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STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

Volume 52, Number 1
JANUARY 1956

CONTENTS

Page
Annual Report of the State Mineralogist for the 106th Fiscal Year.... 8
Sand and Gravel for Concrete Aggregate........ 79

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DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
GOODWIN J. KNIGHT, Governor
DEPARTMENT OF NATURAL RESOURCES
DeWITT NELSON, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

VOL. 52 JANUARY 1956 NO. 1

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STATE OF CALIFORNIA
GOODWIN J. KNIGHT, Governor
DEPARTMENT OF NATURAL RESOURCES
DEWITT NELSON, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

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Third Floor, Ferry Building, San Francisco 11

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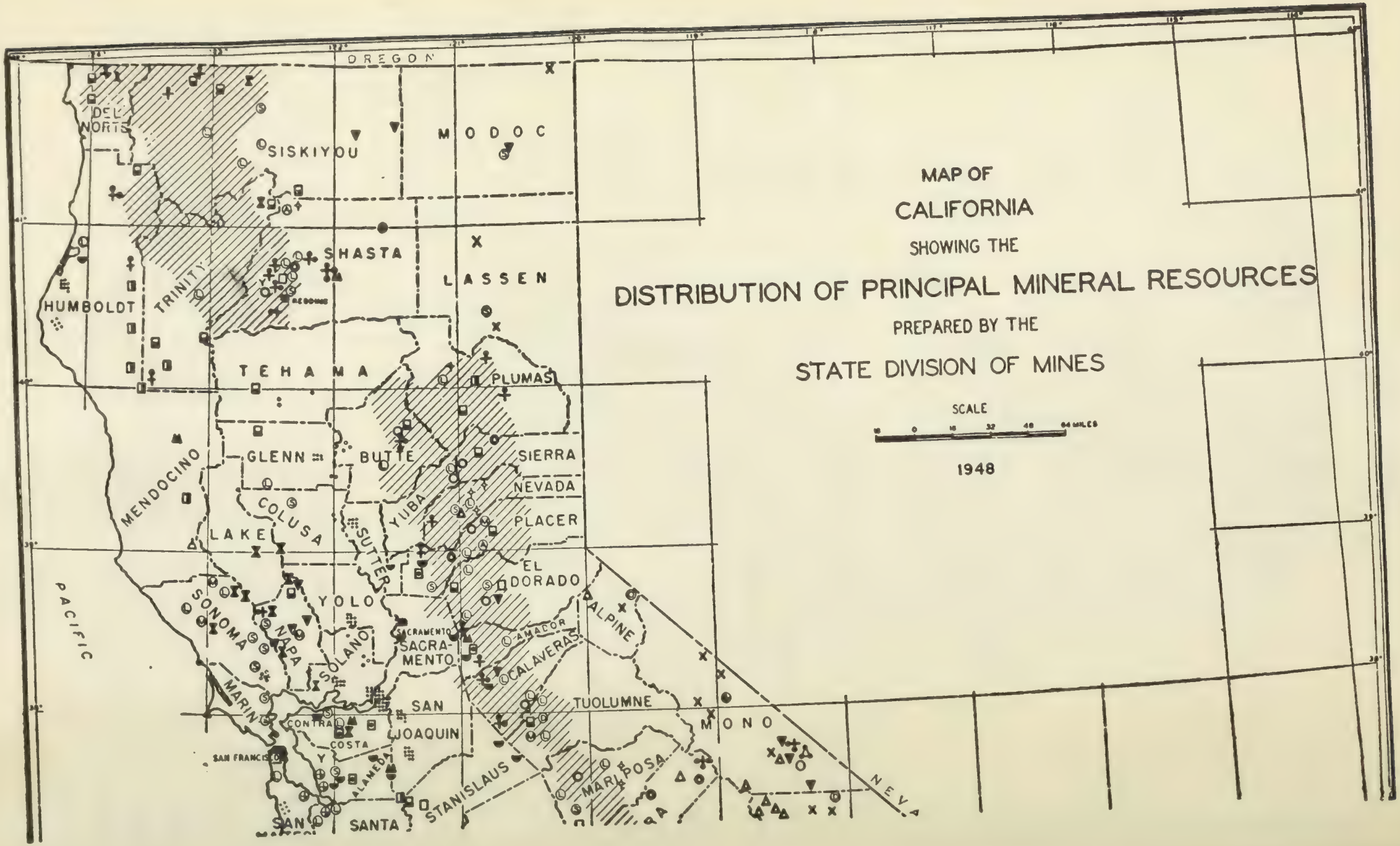
Third Floor, State Office Bldg. 1, Sacramento 14
Department of Natural Resources Building
Cypress and Lanning, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles, Sacramento and Redding branch offices.

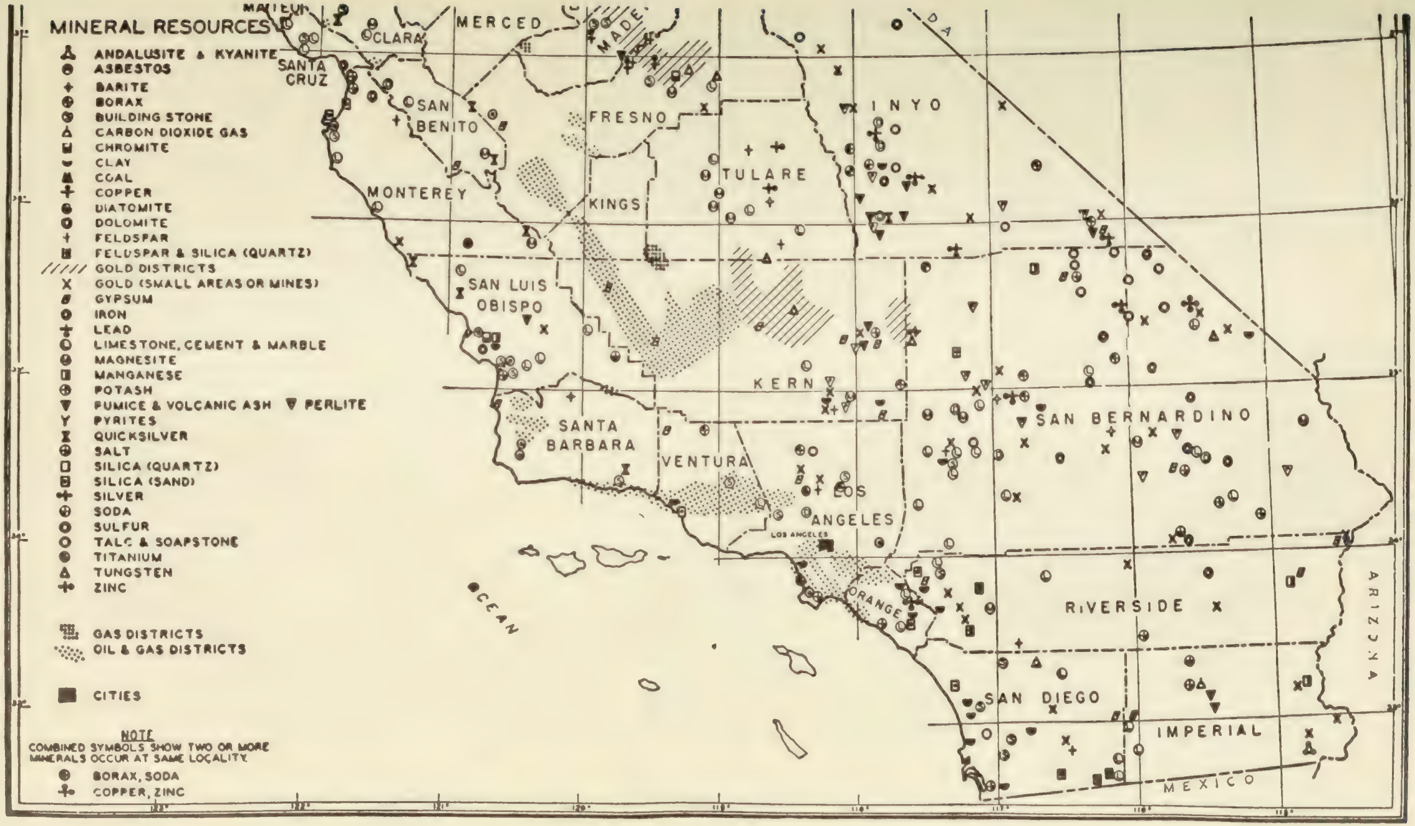
In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are **Bulletins**, **Special Reports**, and the quarterly **California Journal of Mines and Geology**, issued in January, April, July, and October of each year. **Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of available publications will also be sent free upon request.



MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES

SCALE
0
16
32
48
64 MILES
1948
OREGON
NEVA
PACIFIC
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
YUBA
PLACER
COLUSA
LAKE
SUTTER
EL DORADO
ALPINE
SONOMA
NAPA
YOLO
SACRAMENTO
SACRA-MENTO
AMADOR
CALAVERAS
SOLANO
MARIN
TUOLUMNE
MONO
SAN JOAQUIN
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
SAN
SANTA


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY.
BORAX, SODA
COPPER, ZINC
MATEUR
SANTA CRUZ
CLARA
SAN BENITO
MONTEREY
MERCED
MADE
FRESNO
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
ORANGE
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
DA

CONTENTS

Page
Annual Report of the State Mineralogist for the 106th Fiscal Year, by Olaf P. Jenkins 9
Sand and Gravel for Concrete Aggregate, by Harold B. Goldman 79

LETTER OF TRANSMITTAL

MR. DEWITT NELSON
Director, Department of Natural Resources
Sacramento, California

SIR: I have the honor to transmit herewith for reference to Governor Goodwin J. Knight the annual report of the State Mineralogist, Chief of the Division of Mines, for the 106th fiscal year, July 1, 1954 to June 30, 1955. This is in accordance with the requirement in amended Section 2203 of the Public Resources Code. Sections of the Code are quoted throughout the report to give documentary evidence of what is required of the Division of Mines and to show that the program followed adhered to the Code.

In this report, which summarizes the services and activities of the Division of Mines for the fiscal year 1954-55, it is apparent that considerable progress has been made over all preceding years. The expenditures, however, have been held in line and are actually less than last year. The technical work of the Division has won high praise from the public. For the seventh consecutive year, the annual value of California's mineral production has exceeded one billion dollars. The nonmetallic industry, especially, has made notable progress. Minerals for defense have contributed materially to the nation's strategic resources. The demand on the Division of Mines for technical information concerning the mineral resources and mineral industry of the state indicates that this Division is giving material assistance to the economic development of California.

Respectfully submitted,

OLAF P. JENKINS
State Mineralogist and
Chief of the Division of Mines

Ferry Building, San Francisco
September 1, 1955

ANNUAL REPORT OF THE STATE MINERALOGIST CHIEF OF THE DIVISION OF MINES

FOR THE

106TH FISCAL YEAR
JULY 1, 1954 TO JUNE 30, 1955

By Olaf P. Jenkins*

OUTLINE OF REPORT

Letter of transmittal 8
Abstract 10
The mineral wealth of California 10
Administration 17
Financial statement 21
Public information service 22
Mineral laboratory 25
Mineral exhibits 26
Mineral accessions 29
Library 31
Books added to library during fiscal year 1954-55 33
Catalog of an old picture collection in the Division of Mines 40
Map file 44
Public appearances 44
Publications 47
Publications issued during fiscal year 1954-55 48
Publications in press at close of fiscal year 1954-55 50
Popular reports 54
State geologic map 54
Basic geologic mapping 55
Backlog of technical reports 59
Minerals of California 59
Report on earthquakes 60
Bibliography of off-shore geology 60
Mineral commodity surveys 60
Inventories of mining activities 67
Ore buyers' licenses and inspection 68
Los Angeles branch office 69
Sacramento branch office 71
Redding branch office 71
Report of the U. S. Geological Survey 72

Illustrations

Figure 1. Graph showing population and value of mineral production in California since 1905 18
Figure 2. Graph showing relative value of mineral commodities 19
Figure 3. Graph showing number of mineral samples identified 27
Figure 4. Graph showing distribution of schoolite 28
Figure 5. Photo showing safe containing gold specimens 29
Figure 6. Photo showing mineral exhibit 30
Figure 7. Photo showing technical library 32
Figure 8. Photo showing Nevada City, 1852, from collection of historical pictures 39
Figure 9. Map showing progress of geologic map of California 56
Figure 10. Map showing progress of geologic mapping 57
Figure 11. Photo showing deposits of white clay 61
Figure 12. Photo showing geologist in field 61
Figure 13. Photo showing commercial clay deposit 62
Figure 14. Photo showing manganese mine 63
Figure 15. Photo of Ibex talc mine 63
Figure 16. Photo of clay pit 65
Figure 17. Photo of salt processing 66
Figure 18. Photo of large limestone deposit 66
Figure 19. Photo of clay processing plant 68
Figure 20. Photo of quicksilver mine 69
Figure 21. Photo showing staff member testing rock 70
Figure 22. Photo showing interior of Los Angeles Branch Office 72

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* State Mineralogist and Chief of the Division of Mines, Department of Natural Resources.

ABSTRACT

Public Resources Code:

"2203. The State Mineralogist shall make an annual report to the Director for transmission to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature."

The activities and services of the Division of Mines materially increased along all lines during fiscal year 1954-55. The nationwide search for uranium stimulated prospecting for all manner of minerals. The continued increase in the state's population has expanded industry and the demands for information concerning the availability of mineral raw materials. As a result, the Division's information section has been crowded with correspondence, telephone calls, visitors, and sales of publications. The circulation of *Mineral Information Service* increased 30 percent, to over 25,000 per month. The annual sales of publications increased 28 percent, to nearly $46,000. The laboratory identified over 7,000 mineral samples, 39 percent more than last year. Visitors to the mineral exhibits increased 10 times.

These figures represent all-time records for the Division. Accomplishments of staff members in the preparation of technical reports were outstanding. Discoveries of new large mineral deposits of great potential value were made and are currently being studied by the staff. Contributions from authors outside of the Division and cooperative projects with universities and federal agencies were made available through publications which have won praise from the professional world and the public in general. Many completed and processed reports, ready for publication, have built up a large backlog of manuscript material not yet made available because of limited publication funds. The financial statement shows that in spite of increased workload the expenditures of the Division were less by 2½ percent than they were last fiscal year. Favorable comments from the public from all parts of the country and all walks of life, together with a healthy situation of the state's mineral industry, especially in the development of nonmetallic resources, indicate the usefulness of the Division and justify recommendation that adequate support be given for continuation of its fine technical services and activities.

THE MINERAL WEALTH OF CALIFORNIA

Public Resources Code:

"2205. The State Mineralogist shall:

"(a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.

"(b) Collect statistics concerning the occurrence and production of the economically important minerals and the methods pursued in making their valuable constituents available for commercial use."

"2207. The owner, lessor, lessee, agent, manager, or other person in charge of any mine of whatever kind or character within the State shall forward to the State Mineralogist, upon his request, at his office, not later than the thirty-first day of March in each year, upon forms which will be furnished, a report showing the character of the mine, the method of working the mine and the general condition thereof, and the total mineral production for the preceding calendar year. Any such person who fails to comply with the provisions of this section is guilty of a misdemeanor.

"Such reports shall be confidential. Other records are public records unless excepted by statute. Statistical bulletins based on these reports and published

under the provisions of Section 2205 of this code shall be compiled to show, for the State as a whole and separately for each county, the total of each mineral produced therein, provided that, in order not to disclose the production of any operator, no production figure shall be published which represents the production of less than three operators; and when such production figure for any county would conflict with such provision it may be combined with such production figures for one or more other counties. Such bulletins shall be published annually by June 30th or as soon thereafter as practical."

The success of the technical work of the Division of Mines in helping to build a strong mineral industry, firmly entrenched into the economic civilization of the state, is reflected in the value of its minerals produced and utilized. For seven consecutive years (1947-54) the annual value of the mineral production of California has exceeded one billion dollars. About 70 different mineral materials contribute to this natural treasure, and all go into the manufacture of a multitude of useful products—into the fuels and power of industry, into equipment, buildings, highways, and dams, and into the soil to replenish it for the growth of the agricultural products of the state. The value thus added to the state's minerals after they are processed for man's utilization is many fold that of the original raw material. The constant increase in the production and value of California's minerals is attributed to the constant increase in the state's population and its demand for useful products.

The all-time record was in 1953, when the value of mineral output reached $1,392,796,687; it is estimated that the 1954 value will be the second highest on record, or about $1,371,941,000. Since petroleum and related fuels (natural gas, natural gasoline, and liquefied petroleum gases) contribute 80 percent of the total value of mineral production in the state, the 3 percent decline in production of crude petroleum during 1954 reduces the total value slightly from the record figure of 1953.

The production of strategic metals in the state, particularly of value to national defense and research, continued at an accelerated pace during 1954. The value of chromite production was the highest since 1918, during the first world war. The value of manganese ore and concentrates was the highest since World War II. The value of mercury metal recovered from ores was the highest in 10 years. Tungsten ore and concentrate production was also near a record high point.

In the nonmetallic mineral group, the production of commodities useful in the building industry continued at a high level. The quantity and value of cement production increased slightly during 1954, reaching all-time highs.

Large quantities of saline minerals (including borax, salt, gypsum, etc.) are produced annually to supply the needs of various phases of industry. Production of these minerals during 1954 continued at or near the high levels established in the previous year.

The uranium minerals reached the commercial production stage in California in the summer of 1953. While the value is still relatively small, this factual production has provided a tremendous stimulus to the morale of the prospectors. It has induced many newcomers to join the prospecting ranks and thus interest will no doubt lead to additional discoveries.

The value of production in the base and precious metals was considerably below the 1953 figure. Low prices for lead and zinc resulted in the

California mineral production in 1954 (estimated) compared with 1953.

The mineral production in California for 1954 has been estimated at $1,381,839,000, a decrease of less than 1 percent from the 1953 figure. The 1954 estimate, prepared by the U. S. Bureau of Mines in cooperation with the California Division of Mines, is tabulated below.

Commodity	1953		1954 Estimate	
	Quantity*	Value	Quantity*	Value
Chromite (long tons)	26,512	$2,078,461	28,800	$2,347,000
Copper	382	219,268	300	178,000
Gold (fine ounces)	234,591	8,210,685	235,030	8,326,000
Iron ore (long tons)	1,697,652	**	1,250,000	**
Lead	8,664	2,269,968	2,270	631,000
Manganese ore and concentrates (long tons)	17,024	**	35,100	**
Mercury (flasks)	9,290	1,793,249	11,750	3,102,000
Silver (fine ounces)	1,036,372	937,969	296,460	283,100
Tungsten concentrates	2,123	8,906,808	3,000	11,360,000
Zinc	5,358	1,232,340	1,310	288,200
Other metals (manganese, molybdenum concentrates, platinum, rare earth metal concentrates, iron ore)	------	13,932,612	------	11,730,700
Petroleum gases (liquefied) (barrels)	9,466,000	21,961,000	9,300,000	21,600,000
Natural gasoline (barrels)	21,675,000	85,691,000	21,200,000	84,000,000
Natural gas (M cubic feet)	531,346,000	104,675,000	525,000,000	103,400,000
Petroleum (barrels)	364,933,000	908,680,000	354,565,000	902,898,000
Cement (barrels)	32,002,317	90,873,000	31,600,000	94,000,000
Stone (dolomite, granite, limestone, sandstone, sand and gravel, crushed rock)	------	72,127,000	------	68,760,000
Other nonmetallics (asbestos, barite, carbon dioxide, clay, coal, diatomite, feldspar, garnet, gemstones, lime, magnesite, marl, peat, perlite, pumice and volcanic ash, volcanic cinders, quartz, slate, pyrites, sulfur, talc)	------	20,171,022	------	20,430,000
Salines (borates, bromine, calcium chloride, gypsum, iodine, lithium compounds, magnesium compounds, potassium salts, salt, sodium salts, strontium minerals)	------	49,037,305	------	48,505,000
Total value		$1,392,796,687		$1,381,839,000

* Short tons unless otherwise specified.
** See 'Other metals.'

closing of the lead-zinc-silver mines in Inyo County, and caused sharp drops in the production of these metals. Copper production was off slightly. Gold production showed a slight increase over 1953.

The statistical data on mineral production in California are solicited, collected, and processed on a cooperative program by the United States Bureau of Mines and the California State Division of Mines. Preliminary figures and estimates are published by the Division in *Mineral Information Service;* final figures appear in the *California Journal of Mines and Geology,* and in the *Minerals Yearbook* published by the United States Bureau of Mines.

Value of total recorded mineral production in California by substances to and including 1953.

Mineral products in order of total value	Earliest recorded production	Total value to 1953 [a] inclusive	Value of 1953 [a] output	Peak value in	Peak output in	Major producing counties in order of value of mineral output in 1953	Remarks
Petroleum	1865	$12,730,076,026	$908,680,000	1953	1953	Los Angeles, Kern, Ventura, Fresno	California's output is exceeded only by that of Texas. Total value of the petroleum output is greater than the total of all other minerals produced in California.
Gold	1849	2,355,078,046	8,210,685	1852	1852	Nevada, Sacramento, Yuba	Calif. led U.S. in mineral output until 1941, now ranks third.
Cement	1891	1,104,579,528	90,872,741	1953	1953	San Bernardino, Santa Clara, Riverside	Calif. ranks second in output among the states.
Natural gas	1888	1,102,239,314	104,675,000	1953	1948	Los Angeles, Kern, Sacramento, Ventura	Calif. ranks second in output among the states.
Miscellaneous stone	1893	836,740,016	72,127,536	1953	1953	Los Angeles, Alameda, Sacramento, San Diego	Calif. leads U.S. in output of sand and gravel; ranks high among the states in the production of crushed stone.
Borates	1864	249,465,810	17,668,000	1951	1951	Kern, San Bernardino, Inyo	Chief source of world's supply.
Copper	1882	200,025,662	219,268	1916	1909	Inyo, El Dorado, Madera, San Bernardino	Shasta County led from 1897-1918; Plumas from 1919-40; Siskiyou from 1941-44.
Brick and hollow building tile	1893	175,032,616	----	1923	--	------	Not canvassed by U.S. Bureau of Mines. Until 1947 was considered as a mineral product.
Mercury (quicksilver)	1850	153,246,216	1,793,249	1943	1877	San Benito, Sonoma, Lake	Calif. leads U.S. with approximately 64% of total output.
Potash	1914	116,222,012	[b]	1950	1950	San Bernardino	Calif. ranks second in output among the states. 1948 value is not included in the total.
Soda (soda ash and salt cake)	1894	114,066,942	[b]	1953	1951	San Bernardino, Inyo	Calif. leads U.S. in the production of natural sodium carbonates and sulfates.
Tungsten ore	1905	84,807,315	8,906,808	1951	1951	Inyo, Mono, San Bernardino	Calif. led U.S. in 1952.
Silver	1880	79,693,000	937,969	1921	1921	Inyo, Nevada, Sierra	California's output comes from ores of other metals.
Salt	1887	76,868,518	6,263,059	1953	1951	Alameda, San Bernardino, San Diego	Calif. ranks high among the states.
Diatomite	1889	71,414,497	[b]	1951	1951	Santa Barbara, Los Angeles, Napa	Total value to 1951. Calif. is chief source of U.S. supply.

Value of total recorded mineral production in California by substances to and including 1953.—Continued

Mineral products in order of total value	Earliest recorded production	Total value to 1953 [a] inclusive	Value of 1953 [a] output	Peak value in	Peak output in	Major producing counties in order of value of mineral output in 1953	Remarks
Clay (raw)	1887	48,550,231	4,057,074	1953	1952	Riverside, Kern, Los Angeles, Amador	Ranks high among the states. Includes bentonite since 1947 but does not include clay used in cement.
Lime	1894	46,966,527	4,653,303	1953	1953	Monterey, El Dorado, Tuolumne	Lime was included with limestone 1941-46.
Iron ore	1881	43,615,777	12,018,850	1953	1953	Riverside, San Bernardino, Shasta	With the construction of the Fontana steel plant in 1942, production has shown a steady increase.
Lead	1877	42,997,288	2,269,968	1951	1950	Inyo, El Dorado, San Bernardino	Darwin district is principal producing area.
Mineral water	1887	[c]40,601,881	--------	1929	1946	------	Not canvassed by U.S. Bureau of Mines. Represents that which was bottled for sale.
Magnesium compounds (recovered from sea water)	1916	33,738,957	3,483,483	1944	1944	Alameda, Monterey, San Mateo	Calif. ranks second in output among the states.
Zinc	1906	30,831,862	1,232,340	1951	1926	Inyo, Calaveras, El Dorado	Calif. output is by-product of lead and copper mining.
Granite	1887	[c]29,585,027	--------	1925	--	San Diego, Fresno, San Bernardino, Placer	Total included with stone since 1947. Production showed marked decline in recent years.
Gypsum	1887	29,481,886	2,855,983	1953	1952	Imperial, Riverside, Kern, Kings	Demand has been increasing in recent years, for both industry and agriculture.
Limestone	1894	[c]26,075,905	[d]	1946	1946	El Dorado, San Bernardino, Tuolumne	Does not include that used for lime and cement.
Coal	1862	23,570,784	[b]	1880	1880	Amador	Amador County coal is mined for its wax content; is chief source of montan wax in United States.
Talc, pyrophyllite, and soapstone	1893	22,807,479	1,132,700	1952	1952	San Bernardino, Inyo, Mono	Calif. ranks second in output among the states.
Pyrite	1898	20,311,222	[b]	1909	1909	Shasta	Calif. ranks second in output among the states.
Magnesite	1887	19,339,334	[b]	1917	1917	Santa Clara	1947 value not included. Production of natural mineral is declining; magnesia from sea water increasing.
Chromite	1869	16,802,180	2,078,461	1918	1918	San Luis Obispo, Siskiyou, Del Norte	Calif. led the nation in output.

Iodine	1929	16,001,135	[b]	1952	1952	Los Angeles	1947 value not included. Calif. is only producing state.
Silica (quartz and sand)	1899	11,588,501	[b]	1946	1946	Mariposa, San Bernardino	Calif. is an important source of quartz and glass sand.
Pumice and pumicite	1909	10,059,102	451,499	1951	1951	Mono, Madera, Inyo	Calif. led the states in 1951.
Bromine	1926	7,157,450	[b]	1951	1944	San Bernardino, Alameda	Calif. ranks third among the states.
Manganese ore	1887	6,410,216	761,388	1944	1944	Imperial, San Joaquin, San Bernardino	War mineral. Output intermittent.
Paving blocks	1887	[c][d]5,712,288	------	1912	1912	------	No longer used as pavement.
Dolomite	1915	[c]4,971,453	[d]	1946	1946	Monterey, San Benito, Tuolumne	------
Sandstone	1887	[c]4,700,255	[d]	1903	1904	Monterey, Napa	Dimension stone production has decreased in recent years.
Bituminous rock	1887	4,650,320	------	1888	1910	Santa Cruz (in past)	A possible future source of oil.
Barite	1910	3,784,181	[b]	1947	1948	Plumas, San Bernardino	Production irregular in recent years.
Bentonite	1899	[c]3,703,611	----	1928	1928	San Bernardino, Inyo, San Benito	1947-51 output incl. with raw clay. Calif. is important source.
Marble	1887	[c]3,587,755	[d]	1928	--	------	Production declining owing to increased use of artificial stone.
Calcium chloride	1921	3,399,436	[b]	1926	1926	San Bernardino	Calif. ranks second among the states.
Gem minerals	1900	3,131,532	[b]	1943	--	San Diego	1948-49 values not included in total. Includes optical minerals; production irregular and spotty.
Lithium compounds	1899	3,009,110	[b]	1950	1950	San Bernardino	Calif. leads all states.
Molybdenum ore	1916	2,742,118	[b]	1943	1943	Inyo	By-product of tungsten mining.
Slate	1889	2,095,712	[b]	1906	-	El Dorado	Used mostly as granules and fillers.
Carbon dioxide	1894	2,088,564	[b]	1944	1944	Imperial, Mendocino	Calif. ranks second among the states.
Sulfur	1865	1,706,346	[b]	1953	1953	Alpine, Inyo	Alpine County mine went into production in 1953.
Platinum group metals	1887	1,284,090	[b]	1932	1940	Sacramento, Yuba	Calif. ranks first among the states.
Feldspar	1910	1,227,401	[b]	1928	1928	Monterey, San Bernardino	Output small and intermittent.
Sillimanite group	1922	969,919	------	1926	1926	Mono, Imperial (in past)	No output since 1946.
Peat	1935	793,613	73,897	1946	1946	Orange, Contra Costa, Modoc	Sold as a soil conditioner.
Grinding-mill pebbles	1915	358,677	------	1916	1917	San Diego (in past)	Only small output.
Perlite (crude)	1946	334,055	112,790	1952	1952	Inyo, Napa, San Bernardino	Early production included with pumice.
Mineral paint	1890	249,038	------	1893	1903	------	Total incl. with iron ore since 1947. Output small and irregular.
Antimony ore	1887	227,096	------	1916	1916	Riverside (last reported output)	Output small and irregular.
Strontium	1916	213,258	[b]	1943	1943	Imperial	Probably only production in nation.
Mica	1902	198,574	------	1947	1947	------	No reported output since 1947.
Volcanic cinders	1953	196,411	196,411	1953	1953	Siskiyou, Inyo, Modoc	Volcanic cinders previously reported as pumice or crushed stone.
Asbestos	1887	189,135	[b]	1910	1921	Siskiyou, Placer	Both chrysotile and amphibole produced in 1953.

Value of total recorded mineral production in California by substances to and including 1953.—Continued

Mineral products in order of total value	Earliest recorded production	Total value to 1953[a] inclusive	Value of 1953[a] output	Peak value in	Peak output in	Major producing counties in order of value of mineral output in 1953	Remarks
Titanium ore	1927	185,080	------	1928	1928	Los Angeles (in past)	Total to 1947 incl. Several ilmenite occurrences known in Calif.
Onyx and travertine	1887	[c]122,219	[d]	1894	--	------	Output irregular.
Shale oil	1922	109,500	------	1924	--	Santa Barbara (in past)	A future source of oil.
Graphite	1901	87,495	------	1918	1918	------	No output in recent years.
Tin	1891	62,534	------	1892	1892	------	Several occurrences are known in California.
Serpentine	1896	[c]47,218	------	1946	1946	Santa Clara (in past)	1948-49 values not included in total. Is now used in fertilizers.
Garnet (abrasive)	1939	24,795	------	1945	1945	Inyo	By-product from tungsten ore tailings.
Calcium silicate	1933	23,854	------	1938	1838	------	Used in the manufacture of mineral wool.
Cadmium	1917	16,489	------	1917	1917	------	Cadmium reported as a by-product from zinc ores.
Fluorspar	1917	8,912	------	1944	1944	------	Output has been intermittent.
Bismuth	1904	2,400	------	1904	--	------	Some bismuth was concentrated in 1942 but not shipped.
Arsenic	1924	1,356	------	1924	--	------	Production reported only in 1924.
Zircon	1932	1,310	------	1941	--	------	Small amounts of zircon found in most black sand.
Alum minerals	1938	160	------	1938	--	Riverside (in past)	Occurrences have been noted at several places in Calif.
Rare earth minerals	1952	[b]	[b]	1953	1953	San Bernardino	Calif. probably ranks high in national output.
Total recorded value to and including 1953	--------	$20,032,265,532					
Total value for 1953	--------	----------------	$1,392,796,687				

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[a] 1947 to 1953 production figures compiled by U. S. Bureau of Mines. Previous statistics by California State Division of Mines.
[b] Figures appear only in state total for year because this substance was reported by less than three operators.
[c] Total to 1947 inclusive.
[d] 1947 to 1951 output included with miscellaneous stone.

ADMINISTRATION

Public Resources Code:

"2201. The State Mineralogist shall employ competent geologists, field assistants, qualified specialists, and office employees when necessary in the execution of the plans and operations of the division under this chapter.

"2202. The State Mineralogist shall maintain offices, and a museum, library, and laboratory in San Francisco for the purposes provided in this chapter.

"2205. The State Mineralogist shall:

"(a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.

"(g) Maintain, in effect, a bureau of information concerning the mineral industry of this State. . . ."

Public Resources Code:

"507.1. State Mining Board: Members: Appointment: Qualifications: Incumbent members: Filling vacancies: Confirmation of appointments: Organization: Powers: Appointment of employees of Division of Mines. There shall be a State Mining Board, consisting of five members appointed by the Governor with the advice and consent of the Senate for terms of four years and until their successors are appointed and qualified. Members shall be selected from those citizens of this State associated with or having detailed knowledge of the prospecting for, production, processing or marketing of the minerals of this State.

"The members of the incumbent Mining Board, continued in office, shall be classified by the Governor so that the term of office of one member shall expire January 15, 1950, and the terms of two members on January 15, 1951, and January 15, 1952, respectively. An appointment to fill a vacancy occurring before the expiration of a term shall be only for the remainder of that term. All appointments made when the Legislature is not in session shall be subject to confirmation at the next regular or special session of the Legislature. The board shall have power to organize itself and select its officers.

"The board shall represent the State's interest in the development, utilization and conservation of the mineral resources of the State. It is empowered to establish policies conforming to the provisions of state statutes to govern the administration of the Division of Mines.

"The director may authorize the State Mineralogist to exercise his power to appoint employees of the Division of Mines in accordance with the State Civil Service Act. The director may authorize the State Mineralogist or any employee of the Division of Mines to exercise any power granted or perform any duty imposed upon the director by the State Civil Service Act. (Added by Stats. 1949, Ch. 1081, Sec. 2.)"

The Division of Mines represents one of the several divisions of the Department of Natural Resources. The office of the Director of the Department is in the State Building No. 1 in Sacramento. Headquarters offices of the Division of Mines and the office of its Chief, the State Mineralogist, are in the south wing of the Ferry Building, San Francisco. During the fiscal year 1953-54, the offices of the Division were moved from the north wing of the building, where they had been located for many years, to more adequate rooms, better arranged and lighted, and admirably suited to the work of the staff, to serving the public, and to displaying the fine collections of minerals, maps, and books.

The Division of Mines maintains three branch offices, the largest in Los Angeles and smaller ones in Sacramento and Redding, which are all effective in extending the services of the Division to the public and in contacting local industry and research workers. Each carries on many of the phases of the Division's work, except administrative, editorial, drafting, and laboratory.

Two Supervising Mining Geologists, working as a team, assist the Chief in the operations of the entire Division: (1) business management and technical supervision of economic surveys, mining operations and industrial examinations; (2) personnel requirements, and technical supervision of geological and mineralogical surveys. One Senior Mining Geologist is in charge of the Los Angeles office. Three Associate Mining Geologists are assigned special supervisory responsibilities, such as commodity studies, laboratories and exhibits, public information, mineral and industrial inventories.

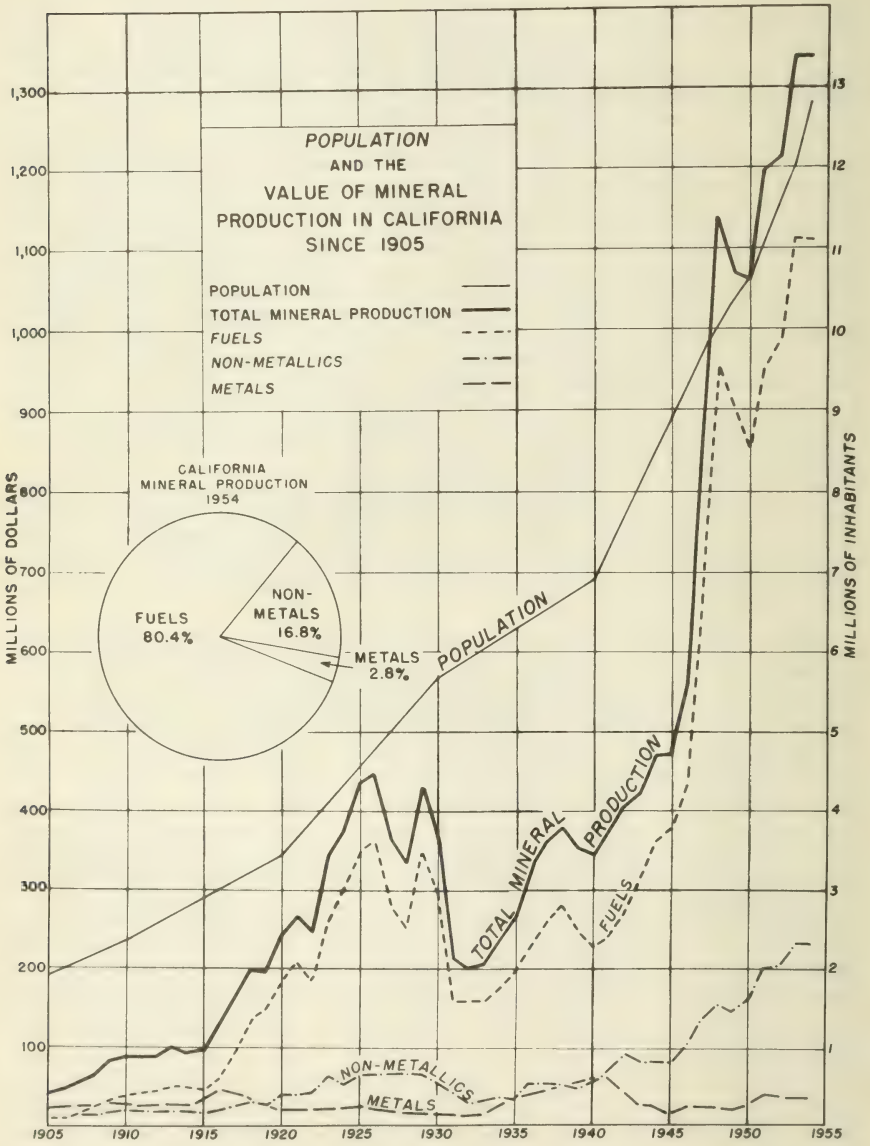

FIGURE 1.

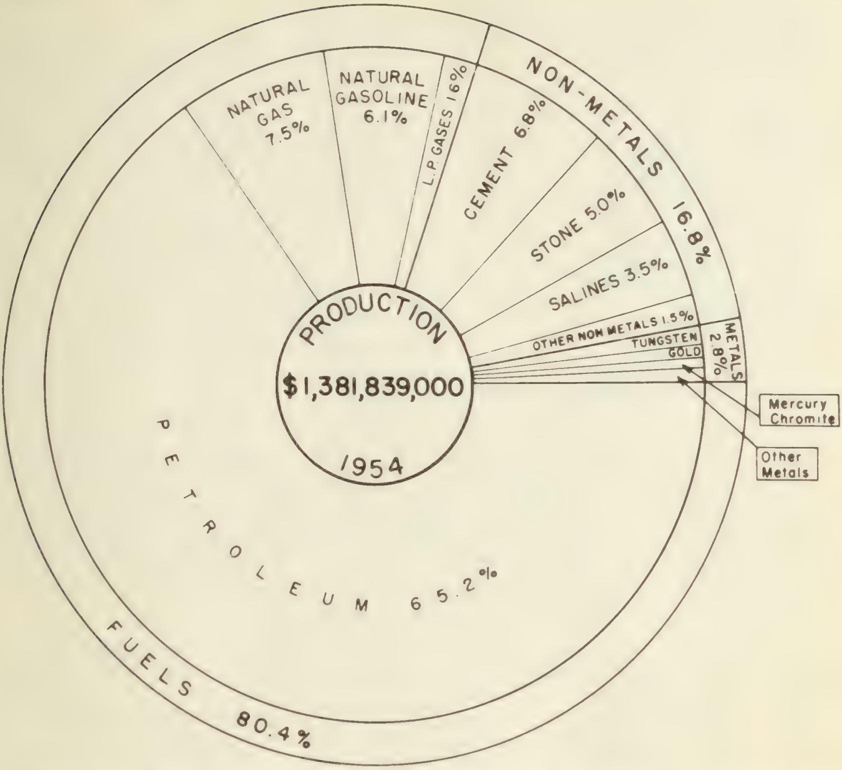

Figure 2. Relative value of the principal mineral commodities produced in California in 1954.

In July 1955 the Division of Mines staff comprised 55 employees—32 technical and 23 stenographic and other non-technical positions. All members of the technical staff are trained in geology, mineralogy, and mining engineering. For reasons of convenience and simplicity, the present classification of *mining geologist* has been adopted for new personnel: supervising, senior, associate, assistant, and junior.

The Editorial Section, comprising two trained geologists, processes all manuscripts for publication. The Drafting Section, supervised by an experienced mining geologist, prepares the charts, maps, and sections necessary for these reports. A trained technical librarian is in charge of the Division's fine library, which serves the public and the staff of the Division. It also acts as a distribution center for school library kits made up of publications of the Division of special interest to teachers and students, and for educational films on the mineral industry, sent upon special request to interested groups.

A list of the technical staff of the Division of Mines on July 1, 1955, follows:

Headquarters office, San Francisco

Olaf P. Jenkins (State Mineralogist and Chief of the Division)

L. A. Norman, Jr. (in charge of business management and mining engineering)

Gordon B. Oakeshott (in charge of personnel and geological surveying)
Oliver E. Bowen, Jr.
Charles W. Chesterman
Fenelon F. Davis
George B. Cleveland
George L. Gary
Harold B. Goldman
J. Grant Goodwin
Earl W. Hart
Charles W. Jennings
Charles J. Kundert
Philip A. Lydon
Marshall E. Maddock
Salem J. Rice
Melvin C. Stinson
Henry H. Symons
William E. Ver Planck
Richard A. Crippen, Jr. (in charge of drafting)
Elisabeth L. Egenhoff (in charge of editing)
Mary R. Hill
William A. Sansburn (in charge of library)

Los Angeles staff
Lauren A. Wright
Richard M. Stewart
Thomas E. Gay, Jr.
Bennie W. Troxel
Cliffton H. Gray
Berdine H. Rogers

Sacramento staff
Denton W. Carlson
William B. Clark

Redding staff
J. C. O'Brien

Each mining geologist, whether or not he may have responsibilities as a supervisor, is assigned special investigations or surveys, such as geologic mapping, commodity studies, mineral inventories, industrial utilization of minerals, or other work required of the Division's Chief. It is intended that results of all of this work will be published and thus made generally available. Major project assignments to staff members as of July 1, 1955, were as follows:

Bowen—Mineral inventory of Mariposa County; study of current research in the Sierra Nevada; special study of the Cherokee hydraulic mine; state-wide commodity survey of cement, dolomite, and limestone.

Carlson—Mineral inventory of Calaveras County; general study of mining operations in the Sierra Nevada; commodity surveys of gold, vein-quartz and quartzite.

Chesterman—State-wide survey of pumice, perlite, and obsidian; geologic mapping of Matterhorn Peak quadrangle; continuous laboratory study of the minerals of California; exhibit studies.

Clark—Mineral inventory of El Dorado County; general study of mining operations in the Sierra Nevada; commodity studies of gold and platinum.

Cleveland—Commodity surveys of clay and lateritic nickel; study of biogeochemical prospecting.

Davis—Commodity surveys of manganese and mercury; statistical surveys; current source book of public information.

Egenhoff—Early documentary history of mineral discovery and operations; continuous technical editorial work.

Gary—Ore buyers inspection; rearrangement of the mineral exhibits.

Gay—Mineral inventory of Kern County; commodity surveys of ferro-alloys, iron, sand and gravel, in southern California; geologic mapping of Coffee Creek area in Klamath Mountains.

Goldman—Commodity surveys of sand and gravel in northern California.

Goodwin—Mineral inventory of Tulare County; preparation of state economic mineral map of lead-zinc; commodity study of cadmium and minor metals.

Gray—Geologic mapping of the Corona quadrangle; commodity surveys of dolomite, limestone, and tin.

Hart—Commodity studies of mineral fuels and data on dry holes drilled outside of producing oil fields; assisting in state-wide limestone survey.

Hill—Special photography, assembling material for Mineral Information Service; technical editing.

Jennings—Mapping of the geology and mineral deposits of Hernandez Valley quadrangle; special investigation of the Vallecitos bentonite; commodity studies on petroleum, coal, peat.

Kundert—Compilation of the new state geologic map, scale 1 : 250,000; commodity survey of barite; geologic mapping in the Calistoga quadrangle.

Norman—Industrial minerals utilization surveys; commodity studies of antimony, arsenic, dimension stone, slate and sulfur.

Oakeshott—Preparation of a bulletin on geology of San Fernando quadrangle; study of the Coast Ranges and Transverse Ranges provinces; commodity studies on diatomite, graphite, and the geologic features of petroleum; study of earthquakes and active faults.

O'Brien—Mineral inventories of Shasta County and Trinity County; commodity studies of copper and zinc.

Rice—General geologic study of the Klamath Mountain province; geologic mapping of coastal area north of Eureka; commodity studies of serpentine products, asbestos, chromite, nickel; editing bulletin on caves of California.

Rogers—Survey of expansible shale resources; detailed survey of clay deposits of Temescal Valley.

Stewart—Mineral inventory of San Diego County; commodity surveys on silver, lead, molybdenum, and tungsten; mineral utilization survey of Los Angeles area.

Stinson—Survey of Island Mountain massive sulfide deposit in northern California; commodity surveys of uranium, rare earth and radioactive minerals; continuous identification of minerals for the public.

Symons—Mineral production statistics and current public information on mining operations.

Troxel—Mineral inventories of Imperial County and Kern County; commodity surveys on abrasives and wollastonite, locally, uranium; geologic mapping of Shadow Mountains.

Ver Planck—Preparation of a bulletin on salt resources of California; special commodity surveys of salines, gypsum, boron minerals; survey of silica commodities.

Wright—Preparation of general state-wide bulletin on the mineral commodities of California; special surveys on beryllium, calcite, feldspar, gemstones, kyanite, mica, pyrophyllite, talc; mapping of the geology and mineral deposits of Shoshone-Tecopa area.

FINANCIAL STATEMENT

In the following financial statement of expenditures for the fiscal year 1954-55, some of the figures given are approximate, because not all bills for the year were paid at the time the report was made. Comparison should be noted, however, of these figures with those of the previous year.

Expenditures 1953-54 (actual)	$484,001
Expenditures 1954-55 (not final)	$471,613

Although the accomplishments of the Division, the distribution of its publications, the services rendered by its staff, and the work load accordingly have all greatly increased during the last fiscal year, the expenditures were less than during the previous fiscal year by $12,388, or about 2½ percent. This fact indicates advancement in personnel experience, better training of personnel, improved integration of the work and cooperation throughout the organization, increased cooperative assistance from outside, and generally greater efficiency of personnel and management.

While holding regular expenditures in line, all this improvement has been accomplished in spite of higher costs, greater demands by the public upon the Division, greater expense in operation of new projects requiring more modern equipment and more highly technical assistance, and difficulty of holding trained employees from leaving the organization for more lucrative positions in industry.

The fact that the Division of Mines has been instrumental in widening the scope of industrial expansion and improving the state's economic standing should be reason enough for giving adequate support to its program of technical and scientific projects. Continued increase in population of California is in direct proportion to continued public demands for information concerning the availability of the state's mineral resources.

Expenditures

*Fiscal 1954-55**

Total salaries and wages		$277,972.59
Operating expenses:		
Freight, cartage and express	$1,918.88	
Telephone and telegraph	2,658.59	
Toll calls	492.54	
Light, heat, power	2,133.57	
Rent of building space	30,756.40	
Repairs and maintenance	372.80	
Office supplies and services	5,173.78	
Postage	9,051.01	
Photography supplies and services	1,188.97	
Blueprinting	900.08	
Printing bulletins and maps	67,794.51	
Printing, general	2,037.60	
Technical reports	1,800.00	
Auto operations—parts, services, gas, oil, tires, tubes	7,751.91	
Travel	13,796.08	
Auto mileage	181.55	
Laboratory supplies and services	3,491.84	
Premiums on bonds	96.60	
Library supplies and services	848.07	
Exhibits supplies and services	204.90	
Total operating expenses		$152,649.68
Equipment:		
Automobile	$1,644.30	
Office	1,309.41	
Miscellaneous replacements	49.08	
Miscellaneous additional	1,348.30	
Library	1,411.11	
Exhibits	228.40	
Total equipment		$5,900.60
Total expenditures		$436,612.87
Special item: Geological exploration in cooperation with U. S. Geological Survey		$35,000.00
Grand total		$471,612.87

* Some of the figures given are approximate, because not all bills for the fiscal year were paid at the time this report was prepared.

PUBLIC INFORMATION SERVICE

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a museum, library, and laboratory in San Francisco for the purposes provided in this chapter.

"2205. The State Mineralogist shall:

". . . (g) Maintain, in effect, a bureau of information concerning the mineral industry of this State. . ."

At the information desk of the Division of Mines are a dozen large volumes of typed material containing the answers to hundreds of questions which are daily asked by the inquiring public. As new difficult questions appear, a current file is kept in this volume of the answers, so that Division staff members, assigned at the information desk, may have ready access to the information. Coordinated with this office is the Division's fine technical library, which serves constantly as the source of all manner of information on geology, mineralogy, mining, metallurgy, chemistry, economics, industry, and related subjects.

In the information office are also distributed over the counter the Division's publications, maps, and pamphlets that tell the story which may be desired by the inquirer.

Outstanding events in the mining world constantly require confirmation, clarification, and explanation by the Division of Mines. This work is handled by the technical staff members, particularly those assigned to the public information section who are in daily communication with the mining public by correspondence, telephone, wire, and personal interview.

Examples of such events occurring during the past year that were the occasion of constant inquiry included: passage of the Multiple Mineral Development Law by the U. S. Congress; release of maps prepared by the Division and federal government showing occurrence of radioactive mineral deposits; publication of a settlement sheet for the first carload of uranium ore shipped from California; announcement of a U. S. Government program to encourage domestic mercury mining; status change of the U. S. Government program for development of strategic minerals; proposed changes in the federal mining law; and the uranium "boom" which inflamed the public mind everywhere with the idea of making a fortune in radioactive mineral discoveries.

The Division is constantly engaged in supplying information on all phases of geology and mining, which is invaluable toward a better understanding and the successful progress of any proposed or established business where minerals and rocks are concerned. Following is a sampling of actual services provided in this category during the year:

Basic Geologic Data. Discussed geology of specific deposits with a prospective Tulare County tungsten producer. Directed research scientist to new information on Paleocene rocks in California. Listed unpublished sources of geologic mapping near Los Banos, for consulting geologist. Introduced an oil company, beginning exploration in California, to geologic literature of the state. Supplied geologic information on Morgan Hill and Sacramento Valley areas to petroleum geologists. Gave geologic data on Año Nuevo Point to Division of Beaches and Parks. Furnished information on geology of southern Coast Ranges to U. S. Army. Supplied chemical firm with information on geology of Contra Costa County. Assisted a general contractor with engineering aspects of the geology along route of a proposed highway construction project.

Provided local water company with data on geology of San Pedro Valley. Informed an eastern paleontologist regarding geology of Sharkstooth Hill area. Gave information on fault locations to Los Angeles County engineers.

Sources of Raw Materials. Provided cement company with information on a limestone occurrence; as a result, the company is now exploring the deposit. Gave data on sources of black granite to interested party. Showed a glass company manager the field occurrence of a possible glass sand. Discussed California mineral commodities with a major chemical company. Pointed out new deposit of chromite to Monterey County miners; as a result, the deposit has produced 17 tons of shipping ore to date. Aided user of garnet for abrasives with data on possible sources of garnet. Advised tile manufacturer on new sources of raw materials in Los Angeles area.

Informed Washington ferro-alloys producer of possible California silica sources. Supplied information on volcanic rocks to a potential pumice producer. Helped smelting company to find southern California sources of pyrophyllite and silica. Informed a steel company on northern California coal, chrome, and iron deposits. Assisted a chemical firm in location of borate deposits. Helped eastern cement manufacturer to select potential site for new plant. Transmitted information on sand and gravel deposits in Los Angeles area to the Division of Water Resources for use in planning Feather River project.

Production and Processing Data. Supplied information on sulfur production to a mineral consultant. Provided zinc mine owner with development data for property. Helped the Division of Corporations with information on a tungsten producer. Assisted new quicksilver producers with data on suitable retorts. Gave facts on current mining activity to machinery and power company engineers.

Made field study of salt industry with representative of Venezuelan government. Supplied a large midwestern manufacturer with geologic data on sand and gravel deposits and statistics on type of crushing equipment used, assisting this firm to forecast the California market potential for its products.

Mineral Utilization and Marketing Data. Provided data and references on the chemical industry. Assisted operator of newly opened talc deposit to find a market for his material. Informed owner of kaolin deposit of possible purchasers. Assisted a company making market survey on sulfur. Gave information to shipyard on characteristics of blast sand in California. Furnished information on marketing of gypsum and washing crude salt. Discussed limestone markets with Stanford Research Institute representatives. Directed owner of calcium chloride deposit to potential buyer of his product.

Physical and Chemical Data on Rocks and Minerals. Assisted one writer preparing a book on rocks and minerals and other writers in preparing books on aids to prospectors. Interpreted spectrographic analyses for prospectors. Identified ''basement'' rock specimens for an oil company. Examined specimens for a sand and gravel producer and advised him regarding reactive constituents.

Mining Law and Documents. Supplied an attorney with information on obtaining a mineral patent. Informed a claim holder regarding state's application for lieu lands which would affect his claims. Provided data on California mining law to Canadian Consul General for use in formulating new laws for Yukon Territory. Gave claim location data on new deposit to manufacturer of pre-stressed masonry. Answered questions on mining law for official of Department of Fish and Game.

Itinerary Planning and Guiding. Conducted group of geology students of the California Institute of Technology on a trip through coal and clay deposits. Conducted group of chemists and physicists on weekend trip through Peninsular Ranges. Led geology students on spring field trip through Amargosa Range. Conducted Geological Society of America groups on field trips in Sonoma, Napa, and Contra Costa Counties.

Led group of state college teachers on trip through Sierra Nevada in Mariposa County. Conducted East Bay area field trip for group of state college students. Planned and guided a group of geologists from the Geophysical Laboratory and eastern colleges on trip through various nonmetallic mineral deposits. Guided a member of New Zealand Geological Survey on trip through northern Coast Ranges and Klamath Mountains. Conducted field trips through Peninsular Ranges, Death Valley, and Transverse Ranges for members of Geological Society of America.

Miscellaneous Services. Assisted an engineer to obtain employment with a California exploration company. Testified before State Senate Committee on mineral resources in proposed Saline Valley withdrawal area. Prepared report on Saline Valley withdrawal for State Mining Board. Assisted historical writer with information on Temescal tin district. Provided State Forester with economic mineral data for conservation publication. Supplied mining information to writers for numerous publications, including Wall Street Journal, Time, San Francisco Chronicle. Discussed mining outlook with investigator for the Department of Investment. Provided references to old mines to investigator of Bureau of Land Management.

Advised a state assemblyman regarding a reported uranium prospect. Assisted state appraiser gathering data on mineral value in Columbia townsite. Helped water pollution control authorities to locate test well, in an oil field. Assisted miners seeking employment by directing them to operating mines. Informed Department of Employment regarding employment opportunities at mines.

The task of supplying information on such a variety of topics has taxed the resources of the Public Information Section in all of its offices to the utmost during the past year. As a result, the program of investigations, which is the life-blood of the organization, has had to suffer. The impact of the uranium prospecting boom is clearly reflected in the enormous increase in all types of services rendered. These increases are enumerated in the following tabulation:

Recorded Information Services

	1953-54	*1954-55*	*Percent change*
Correspondence, telephone*, visitors			
San Francisco office	44,932	71,310	+ 59
Los Angeles office	19,155	41,179	+ 115
Sacramento office	4,048	8,187	+ 102
Redding office	1,873	2,162	+ 15
Incoming pieces of mail, all offices	56,066	75,301	+ 34
Outgoing pieces of mail, all offices	310,627	338,020	+ 8
Mineral Information Service			
Average monthly circulation	19,822	25,792	+ 30
Total publication sales, all offices	$36,671.23	$46,909.07	+ 28

* The count of telephone calls in the San Francisco office is not as complete as in the smaller branch offices, since many of the calls come directly to the technical staff members in San Francisco, and not through the Public Information Office where they are recorded.

MINERAL LABORATORY

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a laboratory in San Francisco for the purposes provided in this chapter."

The mineral laboratory of the Division of Mines serves, in general, two purposes: (1) To identify specimens submitted by the public (as a supplement to the other services rendered the public by the Division); and (2) To serve the staff members of the Division in their assignments, where careful identification of minerals and rocks collected during field investigations are necessary, and testing the properties of materials is required. For the second purpose, the laboratory could well be broadly expanded, both in equipment and technical operation to improve the reports of the Division.

For the public, only qualitative identification of samples is done. If quantitative analyses are needed, the sender of the sample is referred to private laboratories. Only two samples per month per sender are generally accepted, since the present personnel and facilities are inadequate to handle any more than this number.

During the 1954-55 fiscal year, the staff of the Division's laboratory identified 7,020 samples of minerals, ores, and rocks submitted by the public. This is certainly an outstanding accomplishment and represents an increase of 39 percent over the previous fiscal year, 1953-54, which reached an all-time high at that time. Much of this increase is creditable to the uranium boom which was well underway in California as early as 1953. The accompanying graph shows the number of samples identified during the past 9 fiscal years as well as the general upward trend of this activity of the Division.

In their search for fissionable materials the amateur and professional prospectors, as well as the ''rockhounds,'' have uncovered many different kinds of rocks and minerals and submitted them to the Division of Mines for identification.

In addition to the search for uranium, general interest in strategic minerals, including tungsten, quicksilver, manganese, chromium, titanium, and the rare earth elements, has contributed much to the increase in samples.

The Division's laboratory facilities were extensively utilized by members of the staff during the fiscal year. The high-temperature furnace was used to test plates made of a white clay-like material, formed by hydrothermal alteration of rhyolite; this material was recently discovered in large deposits in the desert and proved to be a commercial product as well as a raw material of great potential value in ceramics. The portable differential thermal analysis unit was used to test samples of the nickel mineral garnierite, which occurs in large deposits of laterite developed on old surfaces lying above serpentine; and to identify the clay minerals present in the state's huge deposits of expansible shales. The spectrograph was frequently used to test for trace elements and to make qualitative determinations of samples under investigation by the staff. All microscopes and Geiger counters were in constant use.

MINERAL EXHIBITS

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a museum . . . in San Francisco for the purposes provided in this chapter.

"2205. The State Mineralogist shall: . . .

(c) Make a collection of typical geological and mineralogical specimens, especially those of economic and commercial importance, such collection constituting the museum of the division.

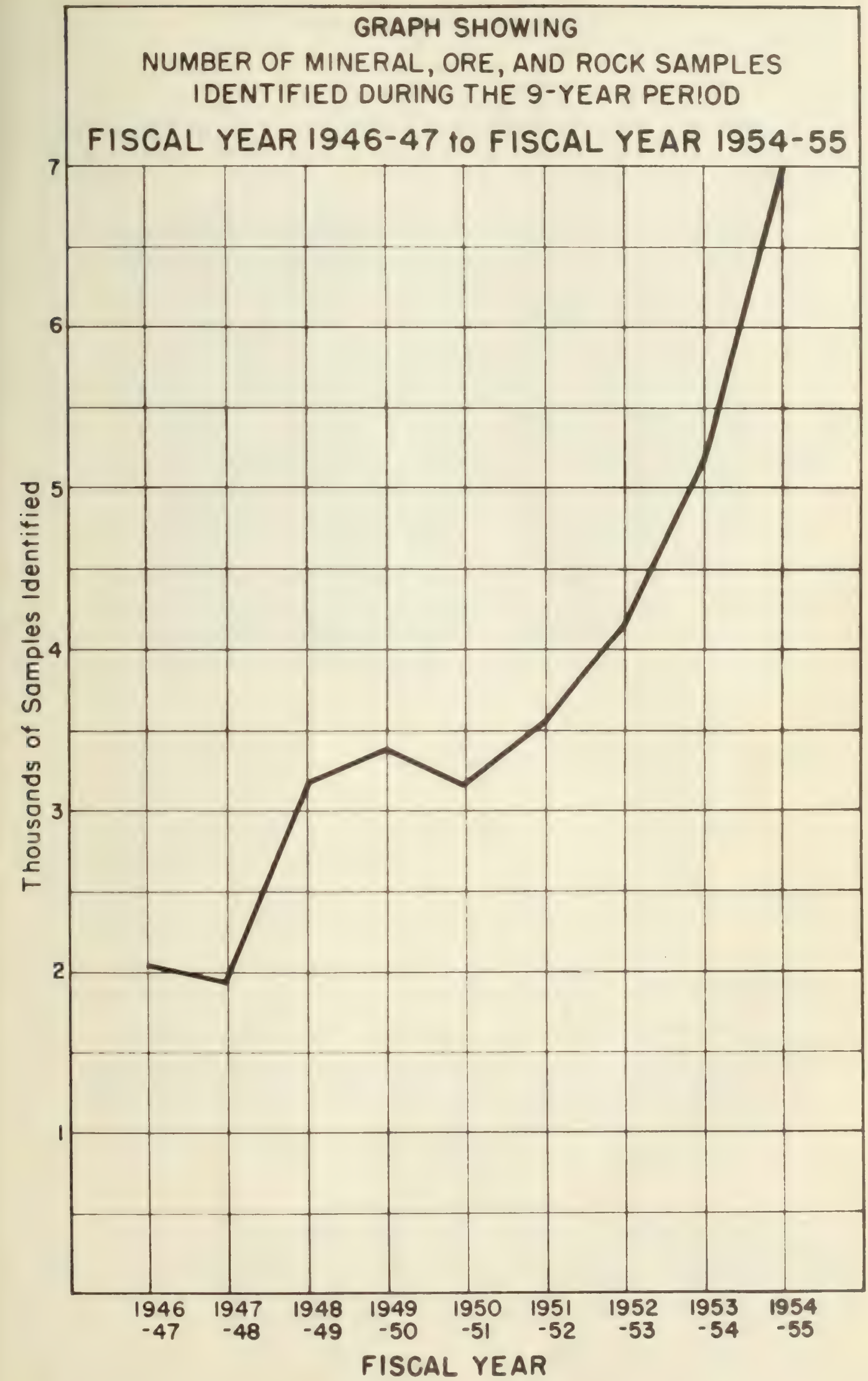
GRAPH SHOWING
NUMBER OF MINERAL, ORE, AND ROCK SAMPLES IDENTIFIED DURING THE 9-YEAR PERIOD
FISCAL YEAR 1946-47 to FISCAL YEAR 1954-55
Thousands of Samples Identified
7
6
5
4
3
2
1
1946 -47
1947 -48
1948 -49
1949 -50
1950 -51
1951 -52
1952 -53
1953 -54
1954 -55
FISCAL YEAR

FIGURE 3.

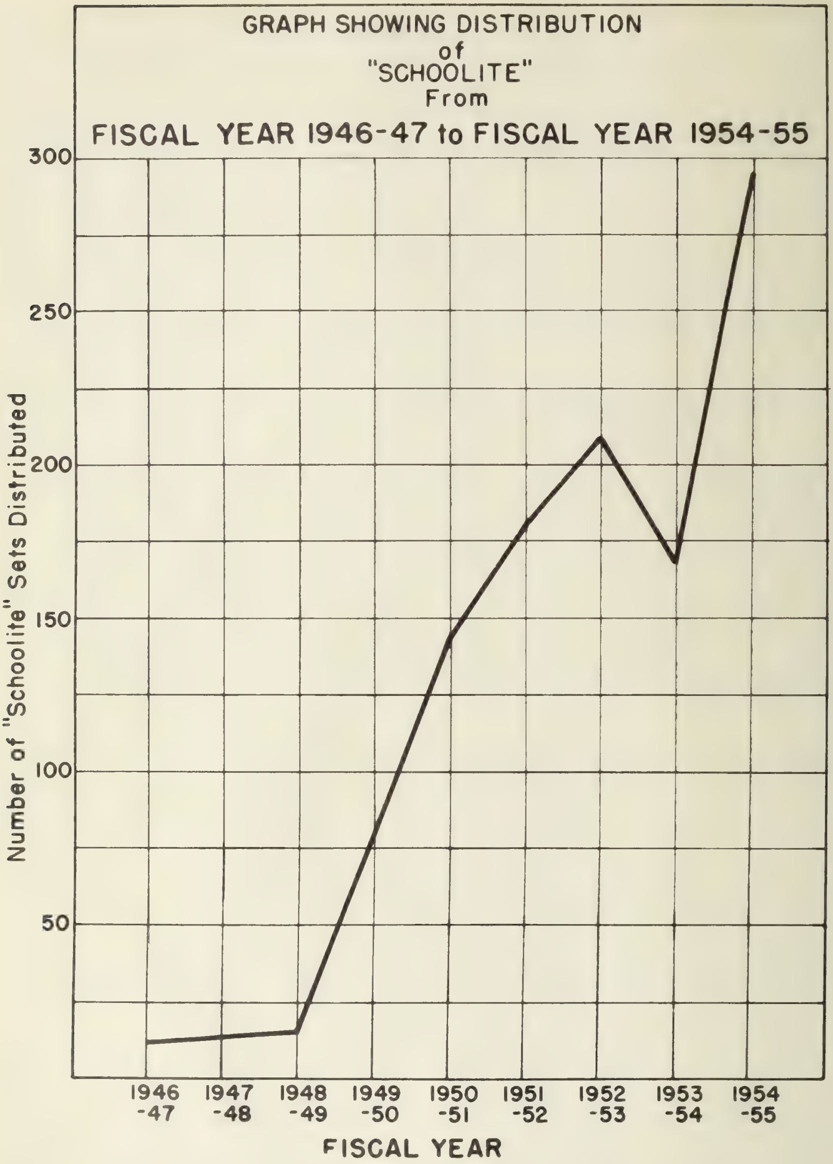

Figure 4.

(e) Make a collection of models, drawings, and descriptions of the mechanical appliances used in mining and metallurgical processes.

"2206. The State Mineralogist may prepare a special collection of ores and minerals of California to be sent to or used at any world's fair or exposition in order to display the mineral wealth of the State."

During the 1954-55 fiscal year the mineral exhibits of the Division of Mines welcomed 36,781 visitors. Approximately 35 percent of these visitors were school children who usually attended in groups of 30 or more. This monthly average of 3,065 visitors to the mineral exhibits

Figure 5. The safe, containing fine specimens of pure gold as it is found in nature, is especially popular. Hundreds of school children each month see the exhibits. *Photo by Mary Hill.*

shows an increase of 10 times the estimated 300 visitors per month during the two previous fiscal years.

Ten new exhibit cases were received and made ready to house the bulk of the minerals that are arranged according to the standard Dana classification of minerals.

The model of the Calaveras cement plant, the stamp mill, the display of fluorescent materials, and the "Mineral of the Month" display are all attractions which command the attention of the visitors.

A total of 288 sets of typical California rocks and minerals (called "schoolite sets" by the Division) was provided on request to elementary schools in California. All requests for these sets were filled including the pending and current. The accompanying graph shows the general upward trend of the distribution of schoolite sets for the past 9 fiscal years.

MINERAL ACCESSIONS

Public Resources Code:

> "2204. The State Mineralogist may receive on behalf of this State, for the use and benefit of the division, gifts, bequests, devices, and legacies of real or other property and may use the same in accordance with the wishes of the donors. If no instructions are given by the donors, the State Mineralogist shall manage, use, and dispose of the gifts, bequests, and legacies for the best interest of the division and in such manner as he may deem proper."

The following specimens were donated to the mineral exhibits of the Division of Mines during the 1954-55 fiscal year:

FIGURE 6. This year 36,781 persons visited the mineral exhibits of the Division of Mines. *Photo by Mary Hill.*

21560 Lepidolite ($K(Li,Al)_3(Si,Al)_4O_{10}(O,OH,F)_2$), hydrous silicate of potassium, lithium, and aluminum, containing 3.50 percent rubidium oxide. From Bikita, South Africa. Donor: Hatten S. Yoder, 1954.

21561 Gold (Au), native gold in quartz. From Beyers and Holterman claim at Hawkins Hill, Hill End, New South Wales, Australia. Donor: J. Paul Jones, 1954.

21562 Cassiterite (SnO_2), tin dioxide in quartz. From Samqunni mine (Ulchin). Samqunni, Semyon, Ulchin Gun, Kwang Won Do Province, South Korea. Donor: Frank A. Crampton, 1954.

21563 Cassiterite (SnO_2), tin dioxide. Placer tin from stream placers. From near Kwan Heung and Kwanak mines, 10 miles south of Seoul, Korea. Donor: Frank A. Crampton, 1954.

21564 Lindgrenite ($Cu_3(MO_4)_2(OH)_2$), hydrous copper molybdate. From Inspiration Consolidated Copper Company's Live Oak mine, 3700 bench, Inspiration, Arizona. Donor: E. F. Reed, 1954.

21565 Cinnabar (HgS), mercuric sulfide on silica-carbonate rock. From Gambonini Ranch, near Marshall, Marin County, California. Donor: John D. Swearingen, 1954.

21566 Copper-lead ore (copper and lead sulfides). From McKinnon Gulch mine, east of Stinson Beach, Marin County, California. Donor: John D. Swearingen, 1954.

21567 Uranoan thorite ($ThSiO_4$), thorium silicate with uranium oxide in allanite-bearing pegmatite. From upper Pacoima Canyon, Trail Canyon quadrangle, Los Angeles County, California. Donor: Gordon B. Oakeshott, 1954.

21568 Struvite ($NH_4MgPO_4 \cdot 6H_2O$), hydrous ammonium magnesium phosphate. From Mt. Widderin Caves, Skipton, Victoria, Australia. Donor: Exchange with Dr. A. W. Beasley, Curator of Minerals, National Museum of Victoria, Russell Street, Melbourne, C. 1, Australia, 1954.

21569 Newberyite ($HMgPO_4 \cdot 3H_2O$), hydrous acid magnesium phosphate. White crystals in guano. From Mt. Widderin Caves, Skipton, Victoria, Australia. Donor: Exchange with Dr. A. W. Beasley, Curator of Minerals, National Museum of Victoria, Russell Street, Melbourne, C. 1, Australia, 1954.

21570 Uraniferous asphaltite in white dolomite. From New Mexico. Donor: James W. Mytton, U. S. Geological Survey, 1954.

21571 Uranium ore. Sample of first ore shipped from California. From Thum Bum mine, San Bernardino County, California. Donor: R. A. Mindte, 1954.

21572 Cinnabar (HgS), mercuric sulfide. From the Greenhouse tunnel area of the Guadalupe mine, Santa Clara County, California. Donor: M. B. Parker, 1954.

21573 Stichtite ($Mg_6Cr_2(OH)_{16} \cdot CO_3 \cdot 4H_2O$), hydrated magnesium and chromium carbonate and hydroxide on magnesite with carnotite. From Clark County, Nevada. Donor: E. M. Thompson, 1954.

21574 Scheelite ($CaWO_4$), calcium tungstate with glassy quartz and green epidote; WO_3 content about 1.5 percent. From Homer Ranch, 6 miles south of Eshom Valley, Tulare County, California. Donor: J. G. Goodwin, 1954.

21575 Garnierite ($H_2(Ni,Mg)SiO_4 \cdot + H_2O$), hydrous silicate of nickel and magnesium. Veins of crystalline garnierite associated with chrysoprase in altered serpentine. From Venice Hills, near Ivanhoe, Tulare County, California. Donor: J. G. Goodwin, 1954.

21576 Amphibole asbestos ($Ca_2(Mg,Fe)_5(OH)_2(Si_4O_{11})_2$), hydrous slicate of calcium, magnesium, and iron. From Venice Hills, near Ivanhoe, Tulare County, California. Donor: J. G. Goodwin, 1954.

21577 Quartz var. chrysoprase (SiO_2), silicon dioxide with green color due to nickel oxide. Gem quality. From Deer Creek, Tulare County, California. Donor: J. G. Goodwin, 1954.

21578 Gold (Au), native gold with arsenopyrite in mariposite, quartz and calcite. From Brush Creek mine, near Downieville, Sierra County, California. Donor: Lou Huelsdonk, 1955.

21579 Gold (Au), native gold. From Ruby mine, Sierra County, California. Donor: City of Six Mining Company, Alleghany, California, 1955.

21580 Kasolite ($Pb(UO_2)(SiO_3)(OH)_2$), hydrous lead uranosilicate. From a pegmatite near Hahn's Peak, Colorado. Donor: C. R. Redington, 1955.

21581 Saléeite ($Mg(UO_2)_2(PO_4)_2 \cdot 8\text{–}10H_2O$), hydrous magnesium urano-phosphate, with autunite and uranophane. From near Golden, Colorado. Donor: C. R. Redington, 1955.

21582 Johannite ($Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$), hydrous copper urano-sulfate, in altered uraninite with zippeite. From the Happy Jack mine, White Canyon, Utah. Donor: C. R. Redington, 1955.

21583 Uraninite (UO_2), uranium oxide. Altered, and with zippeite and uranopilite. From the Happy Jack mine, White Canyon, Utah. Donor: C. R. Redington, 1955.

21584 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$), hydrous potassium urano-vanadate. From Mauch Chunk, Pennsylvania. Donor: R. R. Redington, 1955.

21585 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$), hydrous potassium urano-vanadate. From Mauch Chunk, Pennsylvania. Donor: R. R. Redington, 1955.

21586 Aragonite ($CaCO_3$), calcium carbonate. From near Morro Bay, San Luis Obispo County, California. Donor: Cliff and Mattie White, 1955.

21587 Quartz-wollastonite-uvarovite rock, a mottled green and gray metamorphic rock to which the name Argusite has been applied by the donor. From the east slope of the Argus Range, Inyo County, California. Donor: Eugene A. Bacchi, 1955.

LIBRARY

Public Resources Code:

"2205. The State Mineralogist shall: . . .

(d) Provide a library of books, reports, and drawings bearing upon the mineral industries, the sciences of mineralogy and geology, and the arts of mining and metallurgy, such library constituting the library of the division.

(e) Make a collection of models, drawings, and descriptions of the mechanical appliances used in mining and metallurgical processes.

(f) Preserve and so maintain such collections and library as to make them available for reference and examination, and open to public inspection at reasonable hours.

(g) Maintain, in effect, a bureau of information concerning the mineral industry of this State to consist of such collections and library, and arrange, classify, catalogue, and index the data therein contained, in a manner to make the information available to those desiring it."

The following summary report by the librarian shows the activities and services provided by the Division of Mines library:

Service:	*1953-54*	*1954-55*
Books, periodicals, and maps used by visitors	5,410	9,413
Books, periodicals, and maps used by staff members	3,067	4,964
Foreign exchange list additions	15	11
Library mailing list additions	89	97
Publications issued by stock order	2,997	1,398
School library kits distributed	181	155
Film loans	34	15
Interlibrary loans: Publications loaned out and received on loan, total	31	41
Conservation education: Visits to libraries, schools, professional meetings, and college classes	71	74
Receipts		
Books (By purchase, exchange and donation, including purchases from gift funds)	385	452
Total number of classified books in library by end of fiscal year	9,616	10,078
	1953-54	*1954-55*
Periodicals (San Francisco library subscriptions, branch offices subscriptions, received on exchange, including newspapers	329	319
Maps and charts	1,208	526

FIGURE 7. In the technical library of the Division of Mines, which is open to the public, may be found engineers, geologists, investors, and people in all walks of life. Here authentic information may be obtained on scientific facts of various sorts, descriptions of mineral deposits in all parts of the world, new processes in the mineral industry, and publications covering mineralogy, geology, mining, metallurgy, chemistry, and related subjects. *Photo by Mary Hill.*

During the past year the intensive search for radioactive minerals spread from the Colorado Plateau to the West Coast, and the California uranium-prospecting boom which rapidly developed brought many new inquirers to the Information Section and the Library, accounting for much of the 75 percent increase in the use of books, periodicals, and maps recorded in the Library. Although well supplied with geologic and mining references, and for several years a depository for U. S. Atomic

Energy Commission raw materials reports in the category geology-mineralogy, the Library at first had difficulty in supplying the materials to meet the demands of this new group for information. The need has been met by the appearance of several new journals for uranium prospectors and a growing list of books, from elementary guides to more comprehensive texts such as *Minerals for atomic energy,* by R. D. Nininger. A file of most of the airborne anomaly maps issued by the U. S. Atomic Energy Commission was acquired and since early in 1955, all of the current maps in this series have been received by subscription. With these resources plus the publications of the U. S. Geological Survey, bibliographies issued by the Geological Society of America, and a number of excellent handbooks issued recently by mining bureaus of other states, the Library is well prepared to supplement the work of the Information Section and the Mineral Exhibits Section in providing information to the public on this subject.

Notable acquisitions not given in the accompanying list of classified books includes *Chemical Abstracts* beginning with January 1954. This indexing service to world chemical literature gives extensive coverage of geology, mineralogy, and mineral industries. A 50-year file of the weekly periodical *Science* (American Association for the Advancement of Science) 1889-1948, was obtained by donation from Princeton University Library, and files of American Chemical Society publications and of American Petroleum Institute publications were received from the University of California Library and the Shell Oil Company Library.

The Library's services to readers have been extended during the year by putting into use a microcard and film reader and inexpensive photocopying equipment for convenient reproduction of pages and maps from books without the necessity of sending out the material for photostating. Out-of-print volumes have been obtained on microcards, completing a number of important periodical files.

In the field of conservation education the program of discussing the use of Division of Mines publications in schools and libraries has been continued and institutions and school headquarters in ten counties were visited by the Librarian. Most of the additions to the Library mailing list were California high school libraries and teachers' libraries placed on the list to receive Division of Mines publications as a result of these visits. Addresses were given to two college classes and to a panel of school librarians at a teachers' institute.

Exchange agreements were made with universities and geological surveys in nine countries abroad, adding to the world-wide scope of the Library's collections.

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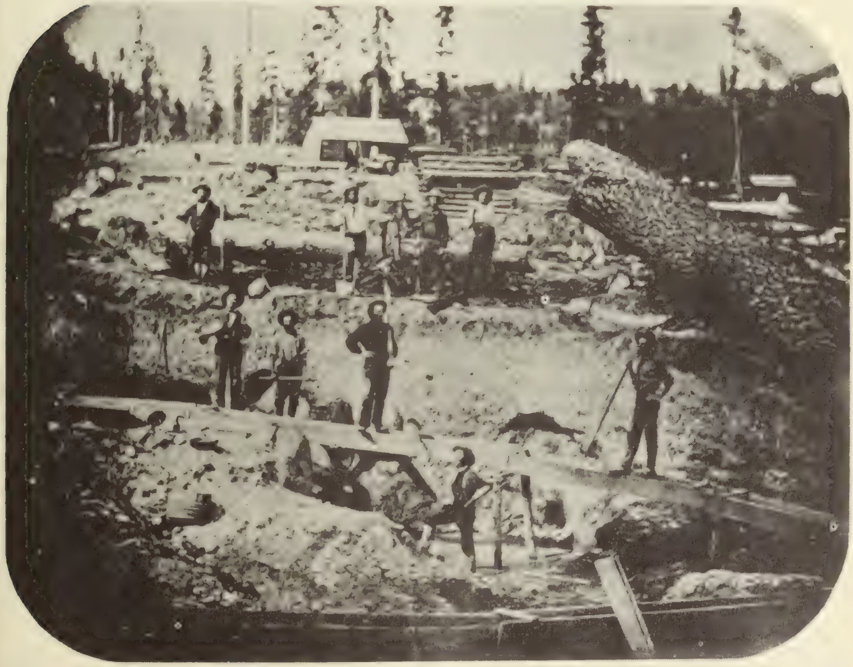

FIGURE 8. Near Nevada City, 1852. Photo in the collection of the Division of Mines.

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CATALOG OF AN OLD PICTURE COLLECTION IN THE DIVISION OF MINES

Stored in one of the rooms of the Division of Mines is a collection of interesting old pictures which recently has been carefully examined and recorded by Prof. Elliott A. P. Evans, Department of Art, Santa Barbara College, University of California. As a result of this examination, Mr. Evans has very kindly submitted a detailed report for record in the Division's files. A part of the report follows:

> ''The picture collection comprises 107 items, paintings, drawings, prints, and photographs. Most are large in size, framed, of outstanding historical importance, and valuable for reference. These pictures fall into five main subject groups:
>
> 1. Portraits of Bureau and Division officials.
> 2. Views of mines and mining operations.
> 3. Drawings and plans of mining structures and devices.
> 4. Awards and diplomas.
> 5. Landscapes and scenes of geological and mineralogical interest.
>
> ''Worthy of particular mention is the large series of fine original photographic views of hydraulic operations to which decorative and period flavor is added by original frames. A series of large photographic reproductions (1870-80) of original rare daguerrotypes of 1852-54, also appropriately framed, is of interest. Another series by the former Mining Bureau photographer, W. L. Watts, showing oil drilling operations at the turn of the century, is also very interesting.''

1. Golden Feather Channel Mine, Butte Co. Cal. no. I Photo, ca. 1870. Panorama, 15½″ x 41″. Framed.
2. Golden Feather Channel Min, No. II. (another view) Photo, ca. 1870. Panorama, 15½″ x 41″. Framed.
3. Portrait, James Marshall, 1887
   Oil on canvas, 22″ x 27″, signed P. L. Peters, 1887.[1] Framed.
4. Portrait, Joseph Wasson.
   Oil on canvass, 25″ x 30″, by P. L. Peters, 1883.[1] Framed.
5. Plan for Timbering, (Comstock, 1860)
   Drawing by Ernest Walser, 1875. Framed.
6. Portrait, Henry G. Hanks, First Director, 1880-86.
   Photo, ca. 1886. 14½″ x 18″. Framed.

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[1] Pearl L. Peters, portrait painter, first appears in San Francisco directory of 1880, Studio 223 Kearney Street. Active in San Francisco. 1880-90?

7. Mining Scene, Mill above a Mountain Lake. (Subject not identified) Oil on canvas, 21″ x 30½″, signed C. L. Haskell.[2] Framed.
8. Trinidad Lake.
   Lithograph, ca. 1920, color. 14″ x 19″. Framed.
9. Portrait, Mr. Fricot.
   Oil on canvass, 19¾″ x 24″, signed, J. Munga,[2] 1893. Framed.
10. Near Sugarloaf Hill, 1852.
    Photo after old daguerreotype. 17″ x 22″. Framed.
11. Group portrait, Messrs. Whitney, Hoffmann, Craven, Goodyear, Rabe. Photo, 1871, 13″ x 16″. Framed.
12. Spanish Flat, 1852.
    Photo. After old daguerreotype. 17″ x 19″. Framed.
13. Near Nevada City, 1852.
    Photo. After old daguerreotype. 16¾″ x 20½″. Framed.
14. Malakof Diggings, no. I, Under Currents.
    Photo, Watkins? ca. 1870. 15¼″ x 21″. Framed.
15. Portrait. Frank Monaghan, Trustee, 1901-05.
    Photo. 12″ x 15″. Framed.
16. Portrait, Thomas B. Bishop, Trustee, President of Board.
    Photo. 12″ x 16″. Framed.
17. Portrait, A. S. Cooper, 1897-1901.
    Photo. 13½″ x 18″. Framed.
18. Portrait, Lewis E. Aubury, Director, 1901-11.
    Photo. 13½″ x 17½″. Framed.
19. Portrait, J. E. Doolittle.
    Photo. 12″ x 16½″. Framed.
20. Portrait, W. S. Keyes.
    Photo. 12½″ x 17″. Framed.
21. Portrait, Harold T. Power.
    Photo. 12″ x 16″. Framed.
22. Portrait, Dr. C. T. Deane, President of the Board, 1910-11.
    Photo, 13″ x 16½″. Framed.
23. Malakoff Diggings, Nevada Co., No. II. (Hydraulic)
    Photo. 15½″ x 21¼″. Framed.
24. Malakoff Diggings, no. III. (Hydraulic, another.)
    Photo. 15¼″ x 21½″. Framed.
25. Malakoff Diggings, no. IV. (Hydraulic, still different)
    Photo. 15½″ x 21½″. Framed.
26. Malakoff Diggings, no. V. Mouth of Tunnel, Humbug Canyon.
    Photo. 15⅝″ x 20″. Framed.
27. Boston Mine, Nevada Co. No. I. (Hydraulic)
    Photo. 15½″ x 21¼″. Framed.
28. French Dam, Nevada Co.
    Photo, ca. 1870-75. 15½″ x 21″. Framed.
29. French Dam, Nevada Co. no. II.
    Photo, ca. 1870. 15″ x 21″. Framed.
30. Blue Tent Ditches, Across the Yuba.
    Photo, ca. 1870. 15″ x 21½″. Framed.
31. Weaver Lake, Nevada Co., Cal.
    Photo. 15½″ x 21″. Framed.
32. Boston Mine, Nevada Co., no. II. (Hydraulic)
    Photo. ca. 1870. 15″ x 21″. Framed.
33. Old Sutter Mill, From a Daguerreotype, 1853-4.
    Photo, 15″ x 21½″. Framed.
34. Near Nevada City, 1852, From a Daguerreotype.
    Photo, ca. 1870. 17″ x 21″. Framed.
35. Deer Creek Water Co.'s Office. From a Daguerreotype. ca. 1852
    Photo, ca. 1870. 17″ x 21″. Framed.
36. Portrait, J. J. Campbell, 1893-97.
    Photo, 14″ x 18″. Framed.
37. Portrait, William Irelan, 1886-93.
    Photo, 14″ x 18½″. Framed.

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[2] Artist not yet identified.

38. Bowman Dam, Nevada County.
    Photo, ca. 1875. 15″ x 21½″. Framed.
39. Nevada City Cala., 1852. From a daguerreotype.
    Photo, ca. 1870. 16¼″ x 21¼″. Framed.
40. Miner's Log Cabin. 1852. From a daguerreotype.
    Photo, ca. 1870. 16½″ x 21″. Framed.
41. Pacific Coast Smelting and Refining Works.
    Photo, Taber. 17″ x 36″. Framed.
42. Mount Shasta, California, Road of a Thousand Wonders. (Southern Pacific R. R.)
    Photo, colored. 18″ x 40″. Framed.
43. La Grange Mine, Trinity County.
    Photo, E. R. Freeman. 7¼″ x 43″. Framed.
44. Cerro Gordo Mine.
    Photo. 9½″ x 39½″. Framed.
45. Hydraulic Mining.
    Photo, colored. 13½″ x 45″. Framed.
46. Cerro Gordo Camp, Looking east.
    Photo. 19¼″ x 25″. Framed.
47. Mining Scene. (Location unidentified.)
    Photo, ca. 1910. 7¼″ x 36½″. Framed.
48. Chino Valley.
    Photo, Watts. 4½″ x 21″. Framed.
49. Sespi Canyon.
    Photo, Watts, 1898. 5″ x 15″. Three views in one mat. Framed.
50. Piru, Ventura County.
    Photo, Watts, 1898. Two views, each 6″ x 15″, in one mat. Framed.
51. La Grange Hydraulic Mine, Trinity County, Calif., no. I.
    Photo, ca. 1910. 9″ x 26¾″. Framed.
52. Section between Piru Peaks and Sta. Clara River.
    Photo, Watts, 1898. 6″ x 24″. Framed.
53. Mill on the California Coast.
    Photo, ca. 1900? 20″ x 24″. Framed.
54. *The Wide West*, June 1, 1856. (Reporting the murder of James Kings of William)
    Newspaper, of date. 21½″ x 28″. Framed.
55. *Columbia Clipper*, EXTRA. Miners Wages.
    Newspaper. 14″ x 20¾″. Framed. Rare.
56. La Grange Hydraulic Mine, no. II.
    Photo. 18″ x 24″. Framed.
57. 40 Stamp Gold Mill. John Hayes Hammond.
    Pen Drawing. 16½ ″ 20½″. Framed.
58. Cross Section of 40 Stamp Mill. John Hayes Hammond.
    Pen Drawing. 16½″ x 20½″. Framed.
59. Device to Regulate the Flow of Water Running through Giants, La Grange Mine.
    Photostat of Original Drawing. 14¼″ x 22″. Framed.
60. Award, Lewis and Clark Centennial, 1905.
    Lithograph. 18½″ x 23½″. Framed.
61. Gold Medal Award, St. Louis Exposition, 1904, for Gold and Gold Ores.
    Lithograph. 16″ x 20″. Framed.
62. Gold Medal Award, St. Louis Exposition, 1904, for Mineral Waters.
    Lithograph. 16″ x 20″. Framed.
63. Gold Medal Award, St. Louis Exposition, 1904, Model Stamp Mill.
    Lithograph, 16½″ x 20″.
64. The Star of Nevada County. (Nuggets arranged as a Star.)
    Photo. 11″ x 13″. Framed.
65. Bell of Nuggets. (Nuggets arranged as a Bell, by Moore of Nevada City)
    Photo. 10½″ x 14″. Framed.
66. Klondike at Home. (Nevada County Nuggets.)
    Photo. 11″ x 14″. Framed.
67. The Bennett Amalgamator, No. I.
    Photo. ca. 1890. 8½″ x 11″. Framed.
68. The Bennett Amalgamator, No. II.
    Photo, ca. 1900. 8½″ x 11″. Framed.

69. The Bennett Amalgamator, No. III.
Photo, ca. 1900. 8½" x 11". Framed.
70. Cie. Fse. des Placers Hydrauliques de Junction City, Trinity Co., Cal., No. I.
Photo. 10" x 13". Framed.
71. Cie. Fse. des Placers Hydrauliques de Junction City, Trinity Co. Cal., No. II.
Photo. 10" x 13". Framed.
72. Kennedy Mine, Amador County.
Photo. 7" x 10". Framed.*
73. 800 F. Station, Zeila Mine, Amador Co. no. I.
Photo. 8" x 10". Framed.*
74. Zeila Mine, Amador Co. no. II.
Photo. 8" x 10". Framed.*
75. Gover (?) Mine, Amador Co. Drift, 600 ft. level, 1891.
Photo. 6" x 10". Framed.*
76. Mercer's Cave, Calaveras Co., no. I.
Photo. 5¾" x 8". Framed.*
77. Mercer's Cave, Calaveras Co., no. II.
Photo. 5¾" x 8". Framed.*
78. Mercer's Cave, Calaveras Co., no. III.
Photo. 5¾" x 8". Framed.*
79. Arrastra, Temperance Flat, Fresno Co.
Photo, 6¼" x 8½". Framed.*
80. La Grange Hydraulic Mine, Oregon Gulch, Cal.
Photo. Framed.*
81. Scene along Trinity River. (Hydraulic)
Photo. 7¾" x 9½". Framed.*
82. Sahlstrom's Gold Mine, Orleans, Humboldt Co.
Photo. 7¾" x 9½". Framed.*
83. State Mining Bureau Exhibit, Home Industries Exposition, 1911.
Photo. 7½" x 9½". Framed.*
84. Stope on 600 ft. level, Grover Mine, Amador Co., Cal.
Photo. 7½" x 9". Framed.*
85. Keystone Mine, Amador Co.
Photo. 7½" x 9½". Framed.*
86. South Spring Mine (?), 800 ft. level, Amador Co.
Photo. 7½" x 10". Framed.*
87. Water Wheel, Klamath River.
Photo. 4¾" x 7½". Framed.*
88. Sutro Tunnel, 1907, 1200 ft. from mouth.
Photo. 6" x 7½". Framed.*
89. Sahlstrom's Gold Mine. (Hydraulic)
Photo. 7½" x 9½". Framed.*
90. South Spring Mine. no. I.
Photo. 7½" x 9". Framed.*
91. South Spring Mine, no. II.
Photo. 7½" x 9". Framed.*
92. Magalia, (Pershbacker) Drift Mine, Butte Co., Cal.
Photo. 6¾" x 9". Framed.*
93. Ten Eyck's Gold Mine. Klamath River.
Photo. 7½" x 9". Framed.*
94. Scene along Trinity River, Humboldt Co.
Photo. 7½" x 9½". Framed.*
95. _____ ___ ? Mine and Mill, Plumas Co.
Photo. 7½" x 9½". Framed.*
96. Zeila Mine, Amador Co., no. III.
Photo. 7½" x 10". Framed.*
97. Share, $10. Philadelphia Centennial Exposition, 1876 (Joseph Wasson)
Engraving. Approx. 17" x 20". Unframed.
98. Portrait, W. A. Goodyear.
Photo, Taber. 10½" x 14". Framed.
99. Dredge
Photo. 14" x 17". Framed.
100. Spherical Concretions, Ventura Co.
Photo, Watts, 1898. 6½" x 8½". Framed.*
Two prints in one mat.

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* Deframe and enter in reference files.

101. Spherical Concretions, Ventura Co.
    Photo, Watts, 1898. 6½″ x 8½″. Framed.*
    Four prints in one mat.
102. Formations in Ventura Co.
    Photo, Watts, 1898. 6½″ x 8½″. Framed.*
    Four prints in one mat.
103. Portrait, C. F. Hoffmann.
    Photo. 11″ x 16″. Framed.
104. Portrait, W. H. Brewer.
    Photo. 11″ x 16½″. Framed.
105. Portrait, J. G. Cooper.
    Photo. 11″ x 16″. Framed.
106. Portrait, W. Ashburner.
    Photo. 11″ x 16″. Framed.
107. Portrait. Wm. Gabb.
    Photo. 11″ x 16″. Framed.

MAP FILE

The Division receives thousands of published maps each year, largely from the United States Geological Survey. A set of these maps constitutes part of the library collection, and in addition many extra copies are needed in the work of the technical staff. A systematic filing of geologic and topographic maps therefore constitutes an important part of the Division's work and service to staff members. The cataloging of these maps is the responsibility of Charles J. Kundert. Approximately 4,000 new maps and charts are annually added to the files. A careful study is made continuously of new maps which cover areas in California, since they have a direct bearing and usefulness in the study of the geology and mineral deposits of the state. In this work, a close cooperation is carried on with the State Division of Water Resources which is the agency of the federal-state cooperation in the making and distribution of topographic quadrangles.

PUBLIC APPEARANCES

Frequently the Division of Mines is requested to supply a speaker on the geology or mineral resources of California, to conduct a field trip through an area of particular interest, to show technical motion pictures from the Division's film library, or to provide publications for display and sale. During the 1954-55 fiscal year, members of the staff attended and participated in a total of 180 meetings, conferences, fairs, and mineral shows; in 1953-54 the total was 170. Fifty-seven talks were given, and 13 separate field trips were conducted. Display of Division of Mines publications was requested at meetings of technical societies, fairs, and mineral shows; during 14 of these, publications were sold in the amount of $5959.89. The following list indicates the type and variety of public appearances during the year.

Technical and Advisory

American Association for the Advancement of Science (1954 annual meeting held in Berkeley)—Organized and led field trip in San Francisco Bay area; attended technical sessions.

American Association of Petroleum Geologists—Attended technical sessions of 1954 annual meeting and sold publications; attended meetings and lectures of Pacific Section throughout the year.

American Ceramic Society, Pacific Coast Regional Conference—Presented paper, attended technical sessions.

American Congress on Surveying and Mapping—Attended meeting in Fresno.

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* Deframe and enter in reference files.

American Institute of Mining, Metallurgical, and Petroleum Engineers—Attended technical sessions of annual meeting in Chicago and presented paper; served as chairman of Mining Branch, Southern California Section; attended monthly meeting in San Francisco and Los Angeles.

American Mining Congress (1954 annual meeting held in San Francisco)—Organized, conducted, and participated in nonmetallics session; attended other technical sessions.

Association of American State Geologists (1955 annual meeting held in Socorro, New Mexico)—Attended technical sessions; served as Secretary-Treasurer.

California Hydraulic Mining Association—Gave talks and showed films at 5 meetings.

California State Chamber of Commerce—Attended meeting of Industrial Plant Location Committee.

Geological Society of America (1954 annual meeting held in Los Angeles,—Presented paper, conducted field trip, assisted registration committee, sold publications, attended technical sessions, published comprehensive bulletin on geology of southern California.

Geological Society of America, Cordilleran Section (1955 annual meeting held in Berkeley)—Presented 3 papers, conducted 3 field trips, acted as chairman of session on stratigraphy, acted on nominating and program committees, attended technical sessions.

Los Angeles Chamber of Commerce Mining Committee—Gave talk, attended meetings and lectures.

Mining Association of Southern California—Attended meetings

Mining Association of the Southwest—Attended meetings

San Francisco Chamber of Commerce Mining Committee—Attended meetings

Western Mining Council—Attended meetings and gave talks at Chapters in Auburn, Plumas County, Santa Rosa, and Shasta County.

Fairs and Mineral Shows

Benicia Gem and Mineral Show

California State Fair—Supplied specimens and assisted with preparation of Shasta County exhibit; constructed model mine exhibit; (judged mining and mineral exhibits); set up mineral exhibit.

Castro Valley Mineral Show

Eureka Mineral Fair

Monterey Bay Mineral Society's Annual Gem and Mineral Show

Redwood Gem and Mineral Show

San Bernardino County Fair

San Francisco Gem and Mineral Society Show

San Luis Obispo Gem and Mineral Show

Santa Cruz Gem and Mineral Society Show

Sonoma County Fair

Stockton Gem and Mineral Show

World Trade Fair (Ferry Building)—The Division of Mines mineral exhibit was kept open to the public during the weekend of this Fair.

Representatives were in continuous attendance throughout most of the above fairs and shows, exhibiting mineral specimens and publications, identifying minerals, giving information on minerals and mining, and selling publications.

Mineral and Geological Societies

Benicia Rock and Gem Club

Cal-Tech Geology Club

Contra Costa Gem and Mineral Society

Castro Valley Gem and Mineral Society

East Bay Mineral Society

El Dorado Gem and Mineral Society

Geological Society of Sacramento—Conducted field trip, attended meetings

LeConte Geological Club—Participated in symposium; served as Chairman of Nominating Committee.

Marin Mineral Society

Monterey Bay Gem and Mineral Society

Northern California Geoolgical Society (AAPG)—Serving as president during 1955.

Palo Alto Geology Society—Conducted field trip.

Peninsula Geological Society—Acted on Program Committee.
Redwood Gem and Mineral Society
San Fernando Mineral and Gem Society
San Joaquin Valley Geological Society (AAPG)
San Mateo Gem and Mineral Society
Santa Cruz Gem and Mineral Society
Standard Oil Rockhounds
Stanford Geological and Mining Society

A total of 22 talks were given to the above societies, as well as the other forms of participation mentioned.

Educational

Association of Geology Teachers—Illustrated talk given
California Institute of Technology—Conducted two student field trips.
California Science Teachers meeting—Talk given
College of Marin, Career Counselling Conference—Acted as counselor on geology as a profession, for senior high school students of Marin County.
Downieville adult education geology class—Talk given
Fresno State College, curriculum for county elementary school teachers—Led field trip.
San Francisco City College geology class—Illustrated talk given
San Francisco State College—Conducted field trip
San Jose State College science class—Gave two talks and showed films.
Stanford University geography class—Talk given
Tulare County Teachers Institute—Exhibited Division of Mines educational materials and addressed meeting of school librarians.
Tulare Schools Science Day Meeting—Displayed publications.
University of California Clay Committee—Participated in meeting.
University of California at Los Angeles, Geology Department—Attended meeting between graduate students and practicing geologists to discuss the profession.
University of Southern California—Spoke at banquet honoring Chairman of Geology Dept.

Business and Industry

Anderson Rotary Club—Spoke on prospecting for uranium.
California Research Corporation—Assisted in conducting sixty chemists and physicists on weekend field trip through the Peninsular Ranges.
Davis Rotary Club—Spoke on the geology of the Sacramento Valley.
Downtown San Francisco Optimists Club—Spoke on radioactive materials.
Menlo Park Kiwanis Club—Gave illustrated talk on geology of California earthquakes.
Redding Rotary Club—Spoke on Shasta County mines and minerals.
Richfield Oil Corporation—Attended lecture and a conservation dinner.
San Bernardino-Riverside Industrial Conference—Presented paper on uranium occurrences in southern California.

Miscellaneous

American Society of Architectural Historians—Served as president of Pacific Section; conducted field trip to visit old Mother Lode mines and buildings.
California Cooperative Summer Camp (Madera County)—Spoke on Sierra Nevada geology.
Marin Art and Garden Show—Answered questions on minerals; sold publications.
Sierra Club—Gave illustrated talk on geology of San Francisco Bay area.
Walnut Creek Women's Society—Spoke on gems and gem materials.

Topics of Talks and Papers

Rocks and minerals of Traverse Creek area, El Dorado County
Geology of Ione area and relation of clay properties to geology
Ceramic raw materials from hydrothermally altered volcanic rocks
Lateritic silicification of serpentine in the Sierra Nevada
Nephrite and associated rocks at Leach Lake Mtn., Mendocino County
Nephrite and jadeite in northern California
Uranium deposits in Arizona and New Mexico
Economic geology and mineral conservation
Activities of Sacramento branch office
Geology of Matterhorn Peak quadrangle

Mineral deposits of Los Angeles County
Berkeley Hills and Point Reyes areas
Geomorphic provinces of California
Franciscan group in southern Coast Ranges
Geology of California earthquakes
Shasta County mines and minerals
Uranium in southern California
Geology of San Francisco Bay area
Geology of Sacramento Valley
Division of Mines services
Geologic history of San Francisco Bay area
Structure of Shadow Mountains
Prospecting for uranium
Geology of Sierra Nevada
Radioactive materials
Gems and gem materials
California uranium
Rainbow Mountain breccias
State geologic maps
Geology of Marin County
Geology of Mt. Diablo
Geology of Modoc County
Bio-geochemical prospecting
Serpentine in California
Quicksilver in California
Amargosa Valley geology
Chromite in California

PUBLICATIONS

Public Resources Code:

"2205. The State Mineralogist shall: ...(h) Issue from time to time such bulletins as he may deem advisable concerning the statistics and technology of the mineral industries of this state."

"2209. The State Mineralogist may fix a price upon and dispose of to the public all publications of the division, including reports, bulletins, maps, registers, or other publications. The price shall approximate the cost of publication and distribution. He may also furnish the publications of the division to public libraries without cost and may exchange publications with geological surveys, scientific societies, and other like bodies."

"2210. All money received by the division from sales of publications issued by the division shall be deposited at least once each month in the State Treasury to the credit of the General Fund. . . ."

Four types of publications are issued by the Division of Mines. All except *Mineral Information Service* (sent gratis) are sold to the public at cost of printing.

(1) *Mineral Information Service.* Monthly (8½″ x 11″) offset press pamphlet, distributed without cost upon request. This has been issued since February 1948.

Through this medium, current information and news of mineral developments are given, statistics and market figures are recorded without delay, announcement of new publications permits wider distribution of results of surveys, and a regular mineral commodity study of great interest to the public is reported. New industries have actually been initiated by this service. By the end of fiscal 1954-55, 35,000 copies were being printed each month.

(2) *California Journal of Mines and Geology.* This is a continuation of the earlier Report of the State Mineralogist started in 1880. Quarterly periodical (paper covered, 6″ x 9″) sold separately ($1.00) or by annual subscription ($3.00). Through the medium of the Journal, an

inventory of the mines of the state is recorded. County reports on the mines and mineral resources, reports on mineral utilization surveys, final statistical figures, and the annual report of the State Mineralogist are published in the Journal. Each county report is accompanied by a tabulated list of mining properties which is coordinated with a mineral map. In this manner the Division maintains a directory of all mines and significant properties of California.

(3) *Bulletins*. Published at irregular intervals (generally cloth covered, standard format 6″ x 9″, but other sizes also used) ; cover statewide surveys, broad-subject monographs, and quadrangle geologic surveys; sold at cost of printing. The bulletin most recently published is No. 169. Though incomplete, Bulletin No. 170 was distributed on a subscription basis during the fiscal year 1954-55.

(4) *Special Reports*. A series (paper covered, 8½″ x 11″), started in December 1950, covering subjects of special concern, but not of statewide scope or of as broad scope as the Bulletin. The last Special Report issued is No. 42.

The following list gives the titles of all publications of the Division of Mines for fiscal 1954-55; it is divided into two parts:

(1) Publications issued during fiscal 1954-55, actually distributed to the public; and

(2) Publications in press at the close of fiscal 1954-55.

PUBLICATIONS ISSUED DURING FISCAL YEAR 1954-55

As the authorship of reports is not limited to the staff of the Division of Mines, the affiliation of each author is shown by one of the following symbols: SDM, member of State Division of Mines; GS, member of U. S. Geological Survey; U, member of a university faculty or student body; C, consultant or member of commercial firm; AEC, Atomic Energy Commission; USBM, U. S. Bureau of Mines; CAS, California Academy of Sciences.

Mineral Information Service

Vol. 7, no. 7, July 1, 1954: Uranium (SDM) ; New topographic maps of California (SDM-GS).

Vol. 7, no. 8, August 1, 1954: California mineral production in 1952 (SDM) ; Price list of available publications of the California State Division of Mines (SDM) ; Mineral marketing information (SDM).

Vol. 7, no. 9, September 1, 1954: Zirconium (SDM) ; List of commercial assay and testing laboratories (SDM) ; Quicksilver (SDM) Topographic maps (SDM-GS).

Vol. 7, no. 10, October 1954: Pozzolans in California, by Frederick W. Drury Jr. (C) ; California topographic maps (SDM-GS) ; Quicksilver purchase program (SDM) ; Specifications and standards of mineral products (SDM) ; Abbott quicksilver mine (SDM) ; Quicksilver mining in New Idria district (SDM) ; Mineral production (SDM) ; Expanded shale (SDM) ; Map of California showing radioactive minerals (GS-SDM) ; Mineral marketing information (SDM) ; Chili Bar slate mine (SDM) ; New mining law; New mining law reviewed (C) ; Location of uranium claims (AEC) ; AEC to terminate uranium circular no. 7 (SDM) ; AEC raw materials office transferred (SDM) ; AEC selects West Coast information depository (SDM) ; First California uranium ore shipped (SDM) ; Uranium report reissued (SDM) ; popular counter handbook revised (SDM) ; Interpreting geologic maps (SDM) ; New literature survey (SDM) ; Uranium bibliography (SDM) ; Essays of William Morris Davis (SDM) ; Wollastonite (SDM).

Vol. 7, no. 11, November 1, 1954: Nickel in California (SDM) ; New uranium occurrence in California (SDM) ; Mort Turner appointed chief geologist of Puerto Rico (SDM) ; Schedule of prices for uranium ore (AEC) ; Classification of uranium deposits by host rock (C) ; Tentative classification of uranium deposits by origin (C).

Vol. 7, no. 12, December 1, 1954: Cadmium (SDM); Additional uranium finds (SDM); Index to volume 7 (SDM); New California topographic maps (SDM-GS); Mineral marketing information (SDM); New report on talc (SDM); First California uranium ore shipment (SDM); "Minerals of California" (SDM).

Vol. 8, no. 1, January 1, 1955: California mineral production in 1954 (estimated) compared with 1953 (SDM); California topographic maps, 1954 (SDM-GS); legal guide reprinted (SDM); New map of San Francisco (SDM); California mineral production in 1953 (SDM); Mineral production in 1953 compared with 1952 (SDM); Mineral production in counties of California 1953 (SDM); Colorado Plateau uranium ore project (C); New report on desert area (SDM).

Vol. 8, no. 2, February 1, 1955: Cement (SDM); French bibliographic digest (SDM); Biography of an oil man (SDM); ASTM standards for coal and coke (SDM); Mineral exhibit features cement plant model (SDM); Types of Geiger counters (SDM); Two wells completed on offshore island (SDM); Alleghany-Downieville lode gold mines (SDM).

Vol. 8, no. 3, March 1, 1955: Bentonite in California (SDM); California topographic maps (SDM-GS); Legal guide out of print (SDM); Barstow bulletin nearly out of print (SDM); Two new books on prospecting (SDM); Manganese purchase program (SDM); New AEC office in Bakersfield (SDM); Copper and uranium (SDM); Scintillation counter designed (SDM); Los Angeles County studied (SDM).

Vol. 8, no. 4, April 1, 1955: Mineral resources of the San Franicsco Bay area (SDM); Wollastonite (SDM); Airborne anomaly maps (GS-SDM); New book for uranium prospectors (SDM); Airborne exploration for uranium (AEC); Mineral marketing information (SDM); National minerals policy (SDM); Bay area guidebook (SDM); World's deepest test well abandoned (SDM); Ubehebe area studied (SDM); New issue of Journal (SDM).

Vol. 8, no. 5, May 1, 1955: Uranium—a comparison of its geologic occurrence in California and in the Colorado Plateau (SDM); New book for uranium prospectors (SDM); Assessment work deadline (SDM); New clay bulletin (SDM); Division offices not damaged in fire (SDM).

Vol. 8, no. 6, June 1, 1955: Clay (SDM); Western Governors mineral policies conference, Sacramento (SDM); New books for geologists (SDM); Foraminifera of the Lodo formation described (SDM); Production and utilization of California petroleum in 1954 (USBM); Newly published USGS topographic maps of California (SDM-GS); New book on clay (SDM); Perlite, Sacramento County featured (SDM).

California Journal of Mines and Geology

Vol. 50, nos. 3 and 4, July-October 1954: The Cool-Cave Valley limestone deposits, El Dorado and Placer Counties, California, by William B. Clark (SDM); Mines and mineral deposits of Los Angeles County, California, by Thomas E. Gay, Jr. (SDM) and Samuel R. Hoffman (SDM); Annual report of the State Mineralogist, Chief of the Division of Mines, for the 105th fiscal year, July 1, 1953 to June 30, 1954, by Olaf P. Jenkins (SDM); Index to volume 50 (SDM).

Vol. 51, no. 1, January 1955: Mineral use in coated welding electrodes, by Richard M. Stewart (SDM); Mines and mineral resources of San Joaquin County, California, by William B. Clark (SDM).

Vol. 51, no. 2, April 1955: The processing of perlite, by H. A. Stein (C) and J. B. Murdoch (C); Mines and mineral resources of Sacramento County, California, by Denton W. Carlson (SDM).

Bulletins

Bulletin 165: Geology and mineral deposits of the Barstow quadrangle, California: Geology and mineral deposits of the Barstow quadrangle, San Bernardino County, California, by Oliver E. Bowen, Jr. (SDM); Thermal properties of ceramic materials from Barstow quadrangle, California, by Joseph A. Pask (U) and Oliver E. Bowen, Jr. (SDM).

Bulletin 169: Clays and clay technology, ed. by Joseph Pask (U) and Mort D. Turner (SDM): INTRODUCTION—Objectives of the first national conference on clays and clay technology, and definition of terms used in the industry, by Ralph E. Grim (U); PART I—Formation and occurrence of clay minerals, by Paul F. Kerr (U); Structural mineralogy of clays, George W. Brindley (U); PART II—Electrochemical properties of clays, by Lannes E. Davis (U); Ion exchange reactions of clays, by D. R. Lewis (C); Adsorptive and swelling properties of clay-water system, by Isaac Barshad (U); Interlamellar sorption by clay minerals, by Douglas

M. C. MacEwan (U); PART III—Particle size distribution in clays, by A. L. Johnson (C); Interpretation of chemical analyses of clays, by W. P. Kelley (U); Interpretation of chemical analyses of montmorillonites, by Bernard B. Osthaus (C); Petrographic study of clay materials, by Ralph E. Grim (U); Dye adsorption as a method of identifying clays, by Charles G. Dodd (C); Infrared analysis of clays and related minerals, by Paul G. Nahin (C); Identification of clay minerals by x-ray diffraction analysis, by George W. Brindley (U); Electron microscopy as a method of identifying clays, by Thomas F. Bates (U); Differential thermal analysis of clays, by Richards A. Rowland (C); PART IV—Role of the physical properties of clays in soil science, by J. B. Page (U); Role of the chemical properties of clays in soil science, by T. F. Buehrer (U); PART V—Importance of clay in applied soil mechanics, by Francis N. Hveem (Calif. Div. Highways); Physical-chemical properties and engineering performance of clays, by Richard C. Mielenz (Bur. Reclamation) and Myrle E. King (Bur. Reclamation); PART VI—Clay technology in ceramics, by Edward C. Henry (U); PART VII—Use of clay in drilling fluids, by Delmar H. Larsen (C); Role of clay in well-log interpretation, by M. R. J. Wyllie (C); Role of clay in oil reservoirs, by Norris Johnston (C); Use of clays as petroleum crack-catalysts, by T. H. Milliken (C), A. G. Oblad (C), and G. A. Mills (C).

Special Reports

Special Report 38: Geology of the Silver Lake talc deposits, San Bernardino County, California, by Lauren A. Wright (SDM).

Special Report 42: Geology of mineral deposits in the Ubehebe Peak quadrangle, Inyo County, California, by James F. McAllister (GS).

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Journal, vol. 49, nos. 1 and 2, January-April 1953: Annual report of the State Mineralogist, Chief of the Division of Mines for the 103d fiscal year, July 1, 1951 to June 30, 1952, by Olaf P. Jenkins (SDM); Mines and mineral deposits of San Bernardino County, California, by Lauren A. Wright (SDM); Richard M. Stewart (SDM), Thomas E. Gay, Jr. (SDM), and George C. Hazenbush (SDM).

Journal, vol. 49, no. 3, July 1953: Flotative properties of titanium minerals in oleate solutions by V. S. Pradhan (U) and D. W. Mitchell (U); Mines and mineral resources of Kings County, California, by Charles W. Jennings (SDM); Absorbent clays in California, by Richard S. Lamar (C).

Journal, vol. 49, no. 4, October 1953: Mines and mineral resources of Mendocino County, California, by J. C. O'Brien (SDM); Index to volume 49 (SDM).

Journal, vol. 50, no. 1, January 1954: Annual report of the State Mineralogist, Chief of the Division of Mines, for the 104th fiscal year, July 1, 1952 to June 30, 1953, by Olaf P. Jenkins (SDM); California mineral commodities in 1951, by Henry H. Symons (SDM) and Fenelon F. Davis (SDM); Mines and mineral resources of Amador County, California, by Denton W. Carlson (SDM) and William B. Clark (SDM).

Special Report 37: Rosamond uranium prospect, Kern County, California, by George W. Walker (GS).

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Mineral Information Service

Vol. 8, no. 7, July 1, 1955: Land subsidence in California (SDM); Earthquake damage at Wilmington (SDM); Cinnabar in San Mateo County (SDM); New topographic maps (SDM-GS); Lead production increased (SDM); New geology text (SDM).

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Vol. 51, no. 3, July 1955: Manganese deposits on the northeast Pacific sea floor, by Robert S. Dietz (U); Mines, mineral resources, and mineral industries of Marin County, California, by William E. Ver Planck (SDM).

Vol. 51, no. 4, October 1955: California mineral commodities in 1952 and 1953, by Henry H. Symons (SDM) and Fenelon F. Davis (SDM); Mines and mineral resources of San Mateo County, California, by Fenelon F. Davis (SDM); Index to volume 51 (SDM).

Bulletins

Bulletin 170, Geology of southern California, ed. by Richard H. Jahns (U). PREFACE, by Richard H. Jahns (U). CHAPT. I, General features: Investigations and problems of southern California geology, by Richard H. Jahns (U); Climate, vegetation, and land use in southern California, by Harry P. Bailey (U); Indian occupation in southern California, by Robert F. Heizer (U). CHAPT. II, Geology of the natural provinces: General geology of the Mojave Desert region, California, by D. F. Hewett (GS); Geology of the Imperial Valley region, California, by T. W. Dibblee, Jr. (GS); Geology of the Peninsular Range province, southern California and Baja California, by Richard H. Jahns (U); Geology of the Oceanside-San Diego costal area, southern California, by Leo George Hertlein (CAS) and U. S. Grant (U); Geology of the Los Angeles basin, by A. O. Woodford (GS), J. E. Schoellhamer (US), J. G. Vedder (GS), and R. F. Yerkes (GS); Geology of the Transverse Range province, southern California, by Thomas L. Bailey (C) and Richard H. Jahns (U); General geology of the offshore area, southern California, by Kenneth O. Emery (U); Geological summary of the San Joaquin Valley, California, by Harold W. Hoots (C), Ted L. Bear (C), and William D. Kleinpell (C); Geology of the Tehachapi Mountains, California, by John P. Buwalda (U); Geology of the central and southern Death Valley region, California, by Levi F. Noble (GS) and Lauren A. Wright (SDM). CHAPT. III, Historical geology: Correlation of sedimentary formations in southern California, by Gordon B. Oakeshott (SDM), Charles W. Jennings (SDM), and Mort D. Turner (SDM); Rocks of Paleozoic age in southern California, by Charles W. Merriam (GS); Mesozoic formations and faunas, southern California and northern Baja, California, by W. P. Popenoe (U); The marine Cenozoic of southern California, by J. Wyatt Durham (U); Fossil foraminifera of the Los Angeles and Ventura regions, California, by M. L. Natland (C) and W. T. Rothwell, Jr. (C); Cenozoic land life of southern California, by Donald E. Savage (U) and Theodore Downs (L. A. County Mus.), with illustrations by Owen J. Poe (U); Marine-nonmarine relationships in the Cenozoic section of California, by J. Wyatt Durham (U), Richard H. Jahns (U), and Donald E. Savage (U); Tertiary basins of southern California, by William H. Corey (C). CHAPT. IV, Structural features: Tectonics of faulting in southern California, by Mason L. Hill (C); A fault map of the Mojave Desert region, by D. F. Hewett (GS); Seismicity of southern California, by Charles F. Richter (U) and Beno Gutenberg (U); Rocks and structure of the northern Providence Mountains, San Bernardino County, California, by John C. Hazzard (C); The San Andreas fault zone from Soledad Pass to Cajon Pass, California, by Levi F. Noble (GS); Strike-slip displacement of the San Gabriel fault, southern California, by John C. Crowell (U); Turtlebacks in the central Black Mountains, Death Valley, California, by H. Donald Curry (C). CHAPT. V, Geomorphology: Some physiographic aspects of southern California, by Robert P. Sharp (U); Geomorphic processes in the desert, by Eliot Blackwelder (U); Physiographic features of faulting in southern California, by Robert P. Sharp (U); Beach and nearshore processes along the southern California coast, by Douglas L. Inman (U); Pleistocene lakes and drainage in the Mojave region, southern California, by Eliot Blackwelder (U); Pleistocene glaciation in the upper San Joaquin Basin, Sierra Nevada, by Joseph H. Birman (U); Marine terraces of the Ventura region and the Santa Monica Mountains, California, by William C. Putnam (U); The nature of Cima Dome, by Robert P. Sharp (U); History of the lower Colorado River and the Imperial depression, by Chester R. Longwell (U). CHAPT. VI, Hydrology: Hydrology of the Los Angeles region, by Harold C. Troxell (GS) and Walter Hofmann (GS); Hydrology of the Mojave Desert, by Harold C. Troxell (GS) and Walter Hofmann (GS); Geology and hydrology of Ventura County, by R. G. Thomas (Cal. Div. Water Res.), E. C. Marliave (Cal. Div. Water Res.), L. B. James (Cal. Div. Water Res.), and R. T. Bean (Cal. Div. Water Res.). CHAPTER VII, Mineralogy and petrology: Minerals in southern California, by Joseph Murdoch (U) and Robert W. Webb (U); Problems of the metamorphic and igneous rocks of the Mojave Desert, by Thane H. McCulloh (U); The batholith of southern California, by Esper S. Larsen, Jr. (U); Miocene volcanism in coastal southern California, by John S. Shelton (U); Pegmatites of southern California, by Richard H. Jahns (U); Contact metamorphism in southern California, by Ian Campbell (U); Contact metamorphism at Crestmore, California, by C. Wayne Burnham (U); Anorthosite complex of the western San Gabriel Mountains, southern California, by Donald V. Higgs (C). CHAPT. VIII, Mineral deposits and mineral industry: Salines in southern California, by William E. Ver Planck (SDM); Deposits of saline minerals in southern California, by Russell

W. Mumford (C); The Mountain Pass rare-earth deposits, by Jerry C. Olson (GS) and Lloyd C. Pray (U); Tungsten in southeastern California, by Paul C. Bateman (GS) and William P. Irwin (GS); Base metal and iron deposits of southern California, by Donald Carlisle (C), Dudley L. Davis (C), Malcolm B. Kildale (C), and Richard M. Stewart (SDM); Gold and silver mining districts in the Mojave Desert region of southern California, by Dion L. Gardner (C); Occurrence and use of nonmetallic commodities in southern California, by Lauren A. Wright (SDM), Charles W. Chesterman (SDM), and L. A. Norman, Jr. (SDM). CHAPT. IX, Oil and gas: History of oil exploration and discovery in California, by Harold W. Hoots (C) and Ted L. Bear (C); Origin, migration, and trapping of oil in southern California, by Frank S. Parker (C); Oil and gas production in California, by Frank B. Carter (C); Stratigraphic traps for oil and gas in the San Joaquin Valley, by Harold W. Hoots (C), Ted L. Bear (C), and William D. Kleinpell (C). CHAPT. X, Engineering aspects of geology: Earthquakes and earthquake damage in southern California, by Charles F. Richter (U); Residential building-site problems in Los Angeles, California, by John T. McGill (U); Subsidence of the Wilmington oil field, California, by U. S. Grant (U). GEOLOGIC GUIDE NO. 1, Geologic guide for the western Mojave Desert and Death Valley region, southern California, by Lauren A. Wright (SDM) and Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 2, Geologic guide through the Ventura Basin and adjacent areas, southern California, by Charles W. Jennings (SDM) and Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 3, Geologic guide for the Los Angeles Basin, southern California, by Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 4, Geologic guide for the southwestern part of the Los Angeles Basin, southern California, by Orville L. Bandy (U) and Kenneth O. Emery (U). GEOLOGIC GUIDE NO. 5, Geologic guide for the northern part of the Peninsular Range province, southern California, by Richard H. Jahns (U). MAP SHEETS: No. 1, Geology of Cuyama Valley and adjacent ranges, San Luis Obispo, Santa Barbara, Kern, and Ventura Counties, by Irving T. Schwade (C); No. 2, Geology of the Tunis-Pastoria Creek area, Kern County, by Paul B. Harris (C); No. 3, Geology of the Sespe Creek-Pine Mountain area, Ventura County, by William R. Merrill (C); No. 4, Geology of the western Ventura Basin, Santa Barbara, Ventura, and Los Angeles Counties, by Thomas L. Bailey (C); No. 5, Geology of a part of the eastern Ventura Basin, Los Angeles County, by Edward L. Winterer (GS) and David L. Durham (GS); No. 6, Geology of the Soledad Basin, Los Angeles County, by Richard H. Jahns (U) and Williams R. Muehlberger (U); No. 7, Geology of the Ridge Basin area, Los Angeles and Ventura Counties, by John C. Crowell (U); No. 8, Geology of the Santa Monica Mountains, Los Angeles and Ventura Counties, by Cordell Durrell (U); No. 9, Geology of the western San Gabriel Mountains, by Gordon B. Oakeshott (SDM); No. 10, Geology of the Little Tujunga area, Los Angeles County, by Benjamin F. Howell, Jr. (U); No. 11, Geologic map of the Owens Valley region, California, by Paul C. Bateman (GS) and C. W. Merriam (GS); No. 12, Geology of the Talc City area, Inyo County, by Thomas E. Gay, Jr. (SDM) and Lauren A. Wright (SDM); No. 13, Geology of the Redrock Canyon-Last Chance Canyon area, Kern County, by T. W. Dibblee, Jr. (GS); No. 14, Geology of the Rosamond Hills, Kern County, by James A. Noble (U); No. 15, Geology of a part of the Shadow Mountains, western San Bernardino County, by Bennie W. Troxel (SDM); No. 16, Geology of the Quail Mountains, San Bernardino County, by William R. Muehlberger (U); No. 17, Geology of the Alexander Hills area, Inyo and San Bernardino Counties, Lauren A. Wright (SDM); No. 18, Geology of the Barstow area, San Bernardino County, by Oliver E. Bowen, Jr. (SDM); No. 19, Geology of the Silurian Hills, San Bernardino County, by Donald H. Kupfer (U); No. 20, Geology of the north side of San Gorgonio Pass, Riverside County, by Clarence R. Allen (U); No. 21, Geology of the Corona-Elsinore-Murrieta area, Riverside County, by Cliffton H. Gray, Jr. (SDM); No. 22, A typical portion of the southern California batholith, San Diego County, by Richard Merriam (U); No. 23, Geology of the Jacumba area, San Diego and Imperial Counties, by Baylor Brooks (U) and Ellis Roberts (U); No. 24, Geology of a portion of Joshua Tree National Monument, Riverside County, by John J. W. Rogers (U); No. 25, Geology of the Carpinteria district, Santa Barbara County, by Harold M. Lian (C); No. 26, Geology of the Rincon oil field, Ventura County, by Robert H. Paschall (C); No. 27, Geology of the San Miguelito oil field, Ventura County, by Richard B. Haines (C) and Francis E. Minshall (C); No. 28, Geology and occurrences of oil in the Ojai-Santa Paula area, Ventura County, by Spencer F. Fine (C); No. 29, Geology of the South Mountain oil field, Ventura County, by E. R. Baddley (C); No. 30, Geology of the Honor Rancho oilfield, Los Angeles County, by Donald G. Herring, Jr. (C); No. 31, Geology of the Placerita oil field, Los Angeles County, by Gordon B. Oakeshott (SDM); No. 32, Geology of the Dominguez oil field, Los Angeles County, by Doyle T. Graves (C); No. 33, Geology of the Wilmington oil field, by Read Winterburn (C); No. 34, Geology of the Long Beach oil field, Los Angeles County, by Paul H. Dudley (C).

Bulletin 171, Earthquakes in Kern County, California, during 1952, Gordon B. Oakeshott, ed. (SDM). PART I, Geology: The Kern County earthquakes in California's geologic history, by Gordon B. Oakeshott (SDM); Geology of the southeastern margin of the San Joaquin Valley, by T. W. Dibblee, Jr. (GS); Kern Canyon lineament, by Robert W. Webb (U); Nature of movements on active faults in southern California, by Mason L. Hill (C); Geological effects of the Arvin-Tehachapi earthquakes, by John P. Buwalda (U) and Pierre St. Amand (U); Ground fracture patterns in the southern San Joaquin Valley resulting from the Arvin-Tehachapi earthquake, by Archer H. Warne (C); Arvin-Tehachapi earthquake damage along the Southern Pacific Railroad near Bealville, California, by Donald H. Kupfer (GS), Siegfried Muessig (GS), George I. Smith (GS), and George N. White (GS); Measurements of earth movements in California, by C. A. Whitten (U. S. Coast & Geodetic Survey); Effect of Arvin-Tehachapi earthquake on spring and stream flow, by Revoe C. Briggs (GS) and Harold C. Troxell (GS); Water-level fluctuation in wells, by G. H. Davis (GS), G. F. Worts, Jr. (GS), and H. D. Wilson, Jr. (GS); Seismic prospecting for petroleum and natural gas in the Great Valley of California, by Joshua L. Soske (C); Application of seismic methods to petroleum exploration in the San Joaquin Valley, by Maurice Sklar (C). PART II, Seismology: General introduction to seismology, by H. Benioff (U) and B. Gutenberg (U); The major earthquakes of California: a historical summary, by V. L. VanderHoof (C); Seismic history of the San Joaquin Valley, by C. F. Richter (U); Seismograph development in California, by Hugo Benioff (U); Seismograph stations in California, by B. Gutenberg (U); Espicenter and origin time of the main shock on July 21 and travel times of the major phases, by B. Gutenberg (U); The first movement in longitudinal and transverse waves of the main shock and the direction of slip, by B. Gutenberg (U); Magnitude determination for larger Kern County shocks, 1952; effects of station azimuth and calculation methods, by B. Gutenberg (U); Foreshocks and aftershocks, by C. F. Richter (U); Mechanism and strain characteristics of the White Wolf fault as indicated by the aftershock sequence, by Hugo Benioff (U); Relation of the White Wolf fault to the regional tectonic pattern, by Hugo Benioff (U); Strong-motion records of the Kern County earthquakes of July 21, 1952, by Frank Neumann (U. S. Coast & Geodetic Survey) and William K. Cloud (U. S. Coast & Geodetic Survey). PART III, Structural damage: Arvin-Tehachapi earthquake—structural damage as related to geology, by G. Schlocker (GS) and Dorothy H. Radbruch (GS); Earthquake damage to oil fields and to the Paloma Cycling Plant in the San Joaquin Valley, by Robert L. Johnston (C); Highway damage resulting from the Kern County earthquakes, by O. W. Perry (Calif. Div. Highways); Damage to waterworks systems, Arvin-Tehachapi earthquake, by H. B. Hemborg (L. A. Dept. Water & Power); Damage to electrical equipment caused by Arvin-Tehachapi earthquake, by G. A. Peers (PG&E Co.); Earthquake damage to railroads in Tehachapi Pass (SPRR); Earthquake damage to elevated water tanks, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald F. Moran (Pacific Fire Bur.); Earthquake damage to California crops, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald F. Moran (Pacific Fire Rating Bur.); Structural damage to buildings, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald E. Moran (Pacific Fire Rating Bur.); The design of structures to resist earthquakes, by G .W. Housner (U).

Bulletin 172, Geology of the San Fernando quadrangle, California, by Gordon B. Oakeshott (SDM).

Special Reports

Special Report 40, Geology of the Calaveritas quadrangle, Calaveras County, California, by Lorin D. Clark (GS).

Special Report 41, Geology of the Angels Camp and Sonora quadrangles, Calaveras and Tuolumme Counties, California, by John H. Eric (GS), Arvid A. Stromquist (GS), and C. Melvin Swinney (GS).

Special Report 43, Geology of a portion of the Elsinore fault zone, California, by John F. Mann, Jr. (U).

Special Report 44, Bibliography of marine geology and oceanography, California coast, by Richard Terry (U).

Reprints

Journal, vol. 50, nos. 3 and 4, July-October 1954: Mines and mineral resources of Los Angeles County, California, by Thomas E. Gay Jr. (SDM) and Samuel R. Hoffman (SDM); The Cool-Cave Valley limestone deposits, El Dorado and Placer Counties, California, by William B. Clark (SDM); Annual report of the State Mineralogist, Chief of the Division of Mines, for the 105th fiscal year, July 1, 1953 to June 30, 1954, by Olaf P. Jenkins (SDM); Index to volume 50 (SDM).

Bulletin 141, Geologic guidebook along Highway 49—Sierran gold belt: Sierran roads of today and yesterday, by Dorothy G. Jenkins (C); The discovery of gold in California, by Donald C. Cutter (U); History of placer mining for gold in California, by Charles V. Averill (SDM); Sierra Nevada province, by Olaf P. Jenkins (SDM); Geologic history of the Sierran gold belt, by Olaf P. Jenkins (SDM); History of mining and milling methods in California, by C. A. Logan (SDM); Geologic maps and notes along Highway 49, by Oliver E. Bowen Jr. (SDM) and Richard A. Crippen Jr. (SDM); The formation of quartz veins, by John A. Burgess (C); Mining on Carson Hill, by John A. Burgess (C); Survey of building structures of the Sierran gold belt, 1848-70, by Robert F. Heizer (U) and Franklin Fenenga (U).

Bulletin 165, Geology and mineral deposits of Barstow quadrangle, San Bernardino County, California: Geology and mineral deposits of Barstow quadrangle, San Bernardino County, California, by Oliver E. Bowen Jr. (SDM); Thermal properties of ceramic materials from Barstow quadrangle, California, by Joseph A. Pask (U) and Oliver E. Bowen Jr. (SDM).

Publications of the California State Division of Mines to July 1, 1955 (SDM).

Legal guide for California prospectors and miners, compiled under the direction of L. A. Norman Jr. (SDM).

Map showing mines and mineral deposits of Inyo County, California (SDM).

POPULAR REPORTS

The revival of interest in prospecting and mining among persons of all ages and occupations was reflected in the sale of Division publications. Leading the best-seller list for the year was the Division's frequently revised handbook on mining law. The present pamphlet is entitled *Legal guide for California prospectors and miners,* and is priced at 25¢. This guide was reprinted twice during the fiscal year, and by the end of the year the fifth printing has been ordered. About 15,000 copies were sold during fiscal 1954-55.

Mineral Information Service was greatly in demand during the fiscal year. Demand for copies of the July 1954 issue, containing an article on uranium, was so heavy that the supply was nearly exhausted within a week of arrival, and reprinting was begun immediately. Two other issues, the October 1954 (containing a summary of the new mining laws) and the May 1955 (containing an article entitled *Uranium—a comparison of its geologic occurrence in California and in the Colorado Plateau*) were of intense interest, judging by the volume of requests.

The demand for the Division's publications to be reprinted is an indication of their popularity. This was certainly true in the case of Bulletin 165 (Barstow Quadrangle), July-October 1954 Journal (Los Angeles report), and Bulletin 141 (Mother Lode guidebook) which is going through its fourth printing.

STATE GEOLOGIC MAP

There is constant demand for a general state geologic map, and for the past 4 years the Division's 1938 issue of the Geologic Map of California, scale 1:500,000, has been out of print. The Division's new project to issue such a map in separate sheets on the scale 1:250,000 is well under way; in fact, 8 of the 30 sheets required are completed. These have been published (at the close of the fiscal year 1954-55) in preliminary form, issued without color, folded in an envelope, convenient for filing, and accompanied by an explanatory sheet, including source data and bibliographies. These preliminary sheets will have limited distribution, subject to correction and revision. Eventually it is intended that they will all appear in color, to show clearly the distribution of each geologic unit.

The Division does not try to map in the field on such a small scale as 1:250,000. This state map is a regional compilation, intended to serve as a clearing house for all detailed field mapping available, published and unpublished. It is considered a continuing project that receives current contributions from various sources, to be integrated on one general scale, using regional rock units of well known geologic divisions. It is in great demand as it is quite usable as a guide in travel, in understanding a region and in project planning. The project has been carried on since 1929 under the supervision of Olaf P. Jenkins; the present compilation is being made by Charles J. Kundert. The following sheets (each named for some outstanding place in its area) are now available at the price of $1.00 each: Santa Maria, Los Angeles, Long Beach, Santa Ana, San Luis Obispo, Bakersfield, Trona, and Death Valley.

BASIC GEOLOGIC MAPPING

The most satisfactory basic research of lasting usefulness in the study of mineral deposits is detailed geologic mapping on topographic base maps. Therefore, the topographic quadrangle maps, issued by the U. S. Geological Survey, are of invaluable service to the Division of Mines in all of its field work. The demand for maps and reports on this base is constant; they are needed for every area of the state.

The Division of Mines' long-range program of basic detailed mapping of the geology and mineral deposits of the state, on quadrangle areas, was continued during the fiscal year 1954-55. Four new reports on geology and mineral deposits, accompanied by colored detailed maps of quadrangles were released: Angels Camp 7½-minute, Calaveritas 7½-minute, and Sonora 7½-minute quadrangles, representing cooperative work with the U. S. Geological Survey; and Barstow quadrangle, 30-minute, mapped by a member of the Division's staff, Oliver E. Bowen, Jr. Five more of this series of colored lithographed quadrangles were completed at the close of the fiscal year, and 66 additional quadrangles were in preparation. The previously published geologic maps of this series continued to be in great demand by petroleum and mining companies carrying on exploration programs, as well as by engineers, agriculturists, and the scientifically interested public. Supervision of the Division's basic geologic mapping program is the responsibility of Gordon B. Oakeshott, Supervising Mining Geologist.

The geologic mapping of quadrangles is done in part by staff members of the Division, in part by professors and graduate students affiliated with universities, in part by private research geologists or geologists who may be affiliated with geological departments of exploration companies, and in part by the U. S. Geological Survey through a cooperative program with the Division of Mines.

Quadrangle mapping projects actively underway by the Division staff include the San Fernando 15-minute quadrangle (geologic map pub-

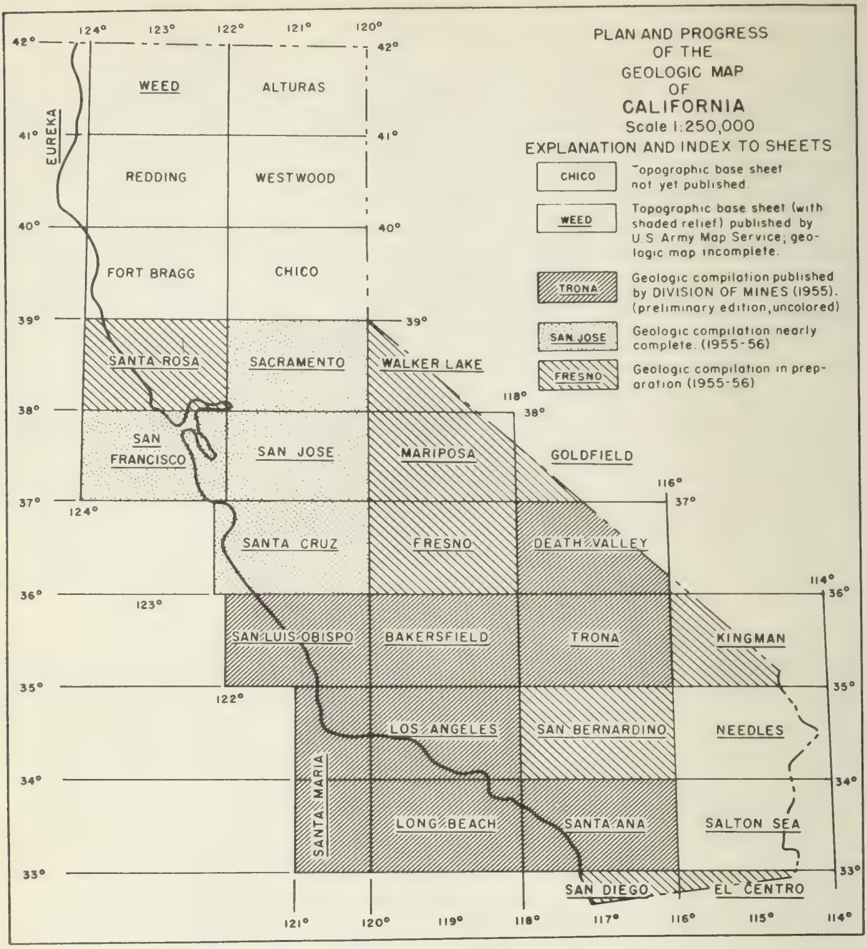
PLAN AND PROGRESS
OF THE
GEOLOGIC MAP
OF
CALIFORNIA
Scale 1:250,000
EXPLANATION AND INDEX TO SHEETS
CHICO
Topographic base sheet not yet published.
WEED
Topographic base sheet (with shaded relief) published by U.S. Army Map Service; geologic map incomplete.
TRONA
Geologic compilation published by DIVISION OF MINES (1955). (preliminary edition, uncolored)
SAN JOSE
Geologic compilation nearly complete. (1955-56)
FRESNO
Geologic compilation in preparation (1955-56)
WEED
ALTURAS
EUREKA
REDDING
WESTWOOD
FORT BRAGG
CHICO
SANTA ROSA
SACRAMENTO
WALKER LAKE
SAN FRANCISCO
SAN JOSE
MARIPOSA
GOLDFIELD
SANTA CRUZ
FRESNO
DEATH VALLEY
SAN LUIS OBISPO
BAKERSFIELD
TRONA
KINGMAN
LOS ANGELES
SAN BERNARDINO
NEEDLES
SANTA MARIA
LONG BEACH
SANTA ANA
SALTON SEA
SAN DIEGO
EL CENTRO
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°

FIGURE 9.

lished, report in preparation) by Gordon B. Oakeshott; Matterhorn Peak 15-minute quadrangle (field mapping completed, report in preparation) by Charles W. Chesterman; Shoshone and Tecopa 15-minute quadrangles (field mapping in progress) by Lauren A. Wright; Calistoga quadrangle, in preparation, by Charles J. Kundert; and Hernandez Valley quadrangle, which is nearly completed, by Charles W. Jennings.

San Fernando quadrangle lies in the western San Gabriel Mountains and marginal areas in Los Angeles County. The area has produced over $50,000,000 in mineral substances including petroleum ($42,000,000), limestone and dolomite, graphite, titanium ore, rock, sand and gravel, and volcanic ash. The old Elsmere Canyon, Whitney Canyon, and Schist oil fields and the active Placerita oil field are in the western part of the quadrangle.

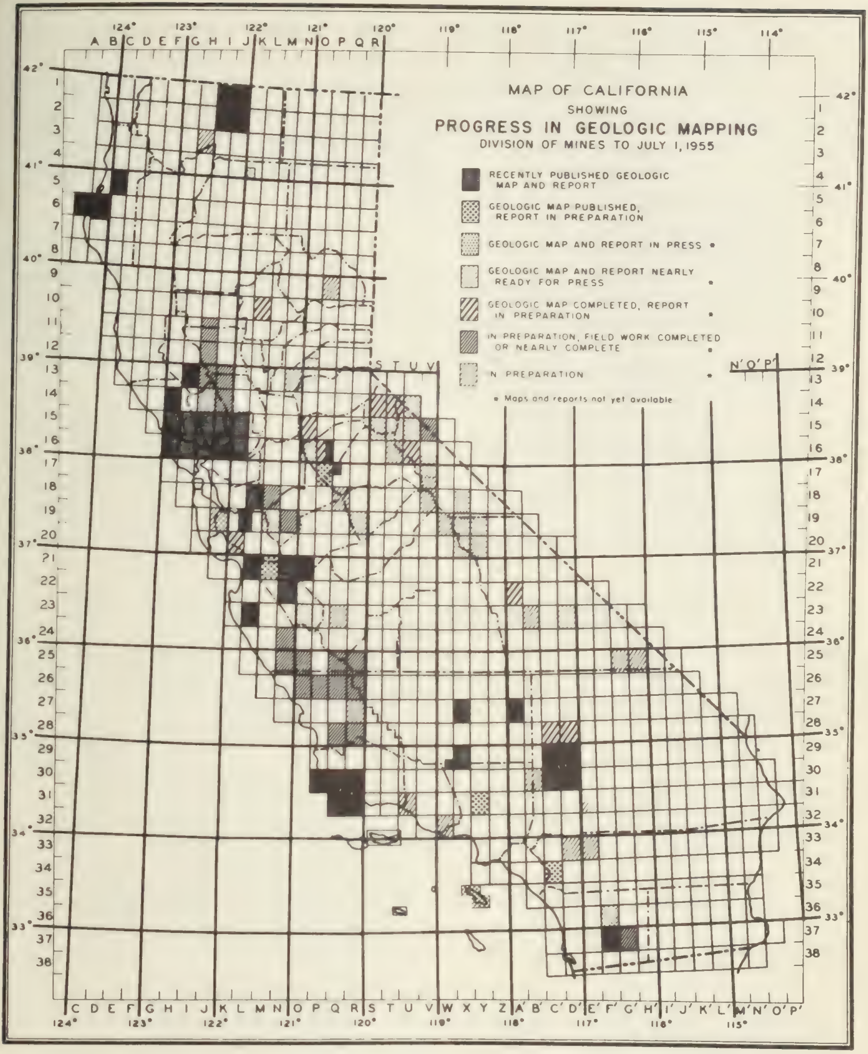
MAP OF CALIFORNIA
SHOWING
PROGRESS IN GEOLOGIC MAPPING
DIVISION OF MINES TO JULY 1, 1955
RECENTLY PUBLISHED GEOLOGIC MAP AND REPORT
GEOLOGIC MAP PUBLISHED, REPORT IN PREPARATION
GEOLOGIC MAP AND REPORT IN PRESS *
GEOLOGIC MAP AND REPORT NEARLY READY FOR PRESS *
GEOLOGIC MAP COMPLETED, REPORT IN PREPARATION *
IN PREPARATION, FIELD WORK COMPLETED OR NEARLY COMPLETE *
IN PREPARATION *
* Maps and reports not yet available
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°

FIGURE 10.

Matterhorn Peak quadrangle lies in the high Sierra Nevada northwest of Mono Lake. In addition to its great scenic attraction, the area is noted for its gold mines and potentialities for tungsten.

Shoshone-Tecopa quadrangles cover a mountainous desert area, for the most part in Inyo County, southeast of Death Valley. Lead, zinc, silver, gold, talc, saline minerals, pumice, and perlite are among the major economic mineral commodities found in this area.

Calistoga quadrangle has produced silver, quicksilver, and sand and gravel.

Hernandez Valley quadrangle, in San Benito and Monterey Counties, has produced lignite and quicksilver but is of greatest current interest for production of oil from the Bitterwater field and a new discovery at Vallecitos, and potential bentonite production from the Idria district.

The following list shows progress of the basic geologic mapping program to July 1, 1955. Only those quadrangles which the State Division of Mines has published or may publish are listed. The quadrangles listed are 15-minute (scale 1:62,500), unless otherwise indicated. The letter preceding the name of the quadrangle indicates the affiliation of the geologists who are doing the work:

D—Division of Mines
U—University geologist
S—Federal Geological Survey (cooperative program)
O—Other professional geologist

The symbol (example, H 15) following the quadrangle name serves as a means of locating it on the accompanying index map.

Recently published geologic map and report:

(S) Angels Camp 7½-min. (P 16)
(U) Antioch (K 16)
(D) Barstow 30-min. (C′ 29, C′ 30, D′ 29, D′ 30)
(U) Blue Lake (C 5)
(O) Breckenridge Mt. (X 27)
(S) Calaveritas 7½-min. (P 16)
(U) Carquinez (J 16)
(S) Cuyamaca Peak (F′ 37)
(U) Ferndale (A 16)
(U) Fortuna (B 6)
(O) Gaviota (R 31)
(U) Healdsburg (G 14)
(U) Jamesburg (L 23)
(U) Lebec 7½-min. (W 29)
(O) Lompoc (Q 30)
(O) Los Olivos (R 30)
(U) Lower Lake (H 13)
(U) Macdoel, 30-min. (I 1, I 2, J 1, J 2)
(U) Mare Island (I 16)
(U) Mount Vaca (J 15)
(S) Neenach (X 29)
(U) Ortigalita Peak (O 21)
(U) Petaluma (H 16)
(O) Point Arguello (P 30)
(O) Point Conception (Q 31)
(U) Point Reyes (G 16)
(U) Quien Sabe (N 21)
(O) Saltdale (A′ 27)
(U) San Benito (N 22)
(U) San Jose (E½)—Mt. Hamilton (W½) (KL 19)
(U) San Juan Bautista (L 21)
(U) Santa Rosa (H 15)
(U) Sebastopol (G 15)
(U) Sonoma (I 15)
(S) Sonora 7½-min. (Q 17)
(U) Tesla (L 18)
(U) Vacaville (K 15)

Geologic map published, report in preparation:

(U) Copperopolis (P 17)
(U) Hollister (M 21)
(O) Lake Elsinore (C′ 34)
(D) San Fernando (Y 31)

Geologic map and report ready for press:

(S) Big Pine (Y 20)
(S) Casa Diablo Mt. (X 18)
(S) Mt. Tom (X 19)
(S) Bishop (Y 19)
(S) Mt. Goddard (X 20)

Geologic map and report nearly ready for press:

(U) Big Bend S.W. (K 4)
(U) Colfax S. ½ (O 12)
(U) Dardanelles Cone (S 15)
(U) Desert Creek Peak (U 14)
(O) Hernandez Valley (O 23)
(S) Santa Catalina Island (X 35, Y 35)
(U) Santa Ysabel (F′ 36)
(U) Sonora Pass (T 15)
(U) West Mono Lake (U 16, 17)
(U) Wheeler Peak (U 15)

Geologic map completed, report in preparation:

(U) Ebbetts Pass (S 14)
(O) Fremont Peak (C′ 28)
(D) Matterhorn Peak (U 16)
(S) New Almaden (K 20)
(S) New York Butte (A′ 22)
(O) Opal Mt. (D′ 28)
(U) Oroville (L 10)
(U) St. Helena (I 14)
(S) San Andreas (P 16)
(U) Sutter Creek (O 15)
(U) Topaz Lake (T 14)

In preparation, field work completed or nearly complete:

(U) Adelaida (O 26)
(U) Bradley (O 25)
(U) Bryson (N 25)
(U) Capay (J 14)
(U) Cape San Martin (M 25)
(U) Carbona (M 18)
(U) Cholame, 30-min. (Q 25, Q 26, R 25, R 26)
(U) Cuyapaipe (G′ 37)
(U) King City (N 24)
(D) Masonic Mt. (V 15)
(U) Nipomo (Q 28)
(U) Orestimba (N 19)
(U) Paso Robles (P 26)

In preparation:

(O) Auburn (N 13)
(U) Banning (E′ 33)
(D) Bodie (V 16)
(U) Blairsden (P 9)
(U) Branch Mt. (R 28)
(D) Calistoga (H 14)
(U) China Mt. (H 3)
(S) Darwin (B′ 23)
(S) Devils Postpile (V 18)
(O) Emigrant Canyon (D′ 23)
(U) Greenville (O 8)
(U) Indian Gulch (R 19)
(U) Joaquin Rocks (Q 23)
(U) Kettle Rock (P 8)
(U) La Panza (R 27)
(U) Ladoga (I 11)
(U) Lucerne Valley (E′ 31)
(U) Merced Falls (Q 18)
(S) Mono Craters (V 17)
(U) Mt. Boardman (M 19)
(U) Mt. Stanford (W 19)
(O) New Idria (P 23)
(U) Palo Alto (J 19)
(U) Perris (D′ 33)
(U) Reiff (I 13)
(U) Rumsey (J 13)
(U) Shadow Mts. (B′ 30)
(D) Shoshone (G′ 25)
(D) Tecopa (H′ 25)
(U) Triunfo Pass (W 32)
(U) Valley Springs (O 16)
(U) Wilbur Springs (I 12)

BACKLOG OF TECHNICAL REPORTS

Besides the long list of quadrangle geologic maps with their accompanying reports in various stages of completion, there are many other projects in the manuscript stage in the backlog files of the Division of Mines, waiting for revision, processing, editing, and publication. Among these are:

Bishop, W. C., Geology of a part of the Santa Susana Mountains, California
Hall, C. A., Brooks, S. A., Jones, D. L., Geology of the Pescadero-Ano Nuevo area
Hutton, C. O., Beach sand mineralogy between Halfmoon and Monterey Bays, California
Johnson, R. F., Geology of the Masonic Mining district, Mono County, California
McLaughlin, D. H., Geology of the Wartham Canyon-upper Jacalitos district, Fresno County, California
Merriam, R., Centers of post-Cretaceous volcanism in San Luis Rey quadrangle, California
Mohr, C. E., Caves of California
Pease, M. H., Jr., Geology of the Sobrante anticline, California
Ross, D. C., Geology of a portion of Sequoia National Park, California
Shawe, D. R., Heavy minerals in stream sands of the eastern Sierra Nevada, California
Shuler, E. H., Geology of the San Timoteo Canyon area, California
Stener, N. B., Tungsten deposits of the Mud Lake district, Fresno County, California

MINERALS OF CALIFORNIA

From the very beginning of the state's organization in 1880 of what was then called the State Mining Bureau, there was need of a volume describing all known minerals in California. Prior to this time, W. B. Blake * published a list of 77 California minerals (1866). The first State Mineralogist issued in 1884 a list of 135 minerals; in 1914, Bulletin 67, written by A. S. Eakle, described 352 mineral species; in 1923 a revised report (Bulletin 91) included 417; in 1938, Bulletin 113 by

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* California Senate and Assembly Jour., 16th sess., vol. 3, 1866, pp. 335-356.

Adolph Pabst described 446; and in 1948 Joseph Murdoch and Robert W. Webb, of the University of California in Los Angeles and Santa Barbara, described in alphabetical order 516 definite minerals and, in addition, many sub-species. These volumes have proved to be increasingly popular, resulting in their going out of print in a comparatively few years after their appearance. The demand for them has required, during fiscal year 1954-55, the revision of Bulletin 136, *Minerals of California* and there is currently in process of editing Bulletin 173 which describes approximately 520 mineral species found in California.

REPORT ON EARTHQUAKES

The most comprehensive bulletin prepared on earthquakes in California since the report of the State Earthquake Investigation Commission on the San Francisco earthquake of 1906 was in press during the close of the fiscal year. This large report covers all phases of the subject, particularly regarding the 1952 earthquakes of the Arvin-Tehachapi-Bakersfield area. The volume represents a symposium contributed by 36 authoritative scientists and engineers and edited by the Division of Mines. The earthquake faults of California and their movements represent outstanding features in the study of the geology and mineral resources of California, besides being great hazards to construction, transportation, water supply, oil drilling, as well as to life. The study of seismology has thrown much light on the structure of the earth and the properties of rock bodies. The publication of this Bulletin 171 was requested by several groups of engineers and geologists, many of whom contributed technical papers for the volume.

BIBLIOGRAPHY OF OFF-SHORE GEOLOGY

The subject of oceanography, coast processes of erosion and deposition, coast geology, submarine geology, and off-shore conditions in general are of concern to several different active agencies, as for example: Off-shore drilling companies searching for new oil and gas pools, navigation, national defense, State Division of Beaches and Parks, mining companies using sand and pebble deposits on the beaches and geologic studies of potential submarine deposits of phosphate and manganese. Recently Richard D. Terry contributed to the Division of Mines for publication a comprehensive bibliography entitled ''Bibliography of marine geology and oceanography.'' This report was in press at the close of the fiscal year 1954-55.

MINERAL COMMODITY SURVEYS

Up-to-date reports on mineral commodities of California are needed at all times to meet the demand of nearly all the inquiring public, especially investors and people interested in location of manufacturing plants that use mineral raw materials. Such reports should cover all phases of the subject: mineralogy, technology, geology, occurrence, potential sources, grade, usefulness, availability, transportation, mining, production, imports, market specifications—that is, all data available. To keep abreast of this general information, each member of the technical staff is assigned certain mineral commodities so as to become a specialist in this work. Detailed field studies are being carried on continually on certain commodities of special and occasional interest and

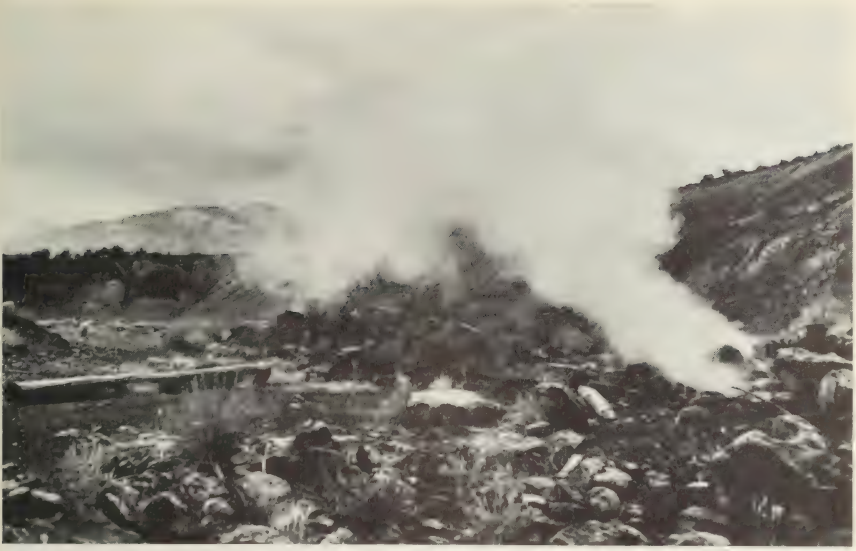

FIGURE 11. Huge deposits of white clay have been formed by the action of hot springs on the volcanic rock rhyolite. This photo shows hot springs near Casa Diablo, which are some of the springs responsible for altering rocks to these clays. *Photo by Mary Hill.*

FIGURE 12. Division geologist taking readings of dip and strike of beds in order to map the geologic structure of the rocks related to clays in the Casa Diablo region. *Photo by Mary Hill.*

a general compilation is being made which is intended to serve as a text for daily ready reference.

The Division's continuous survey of mineral utilization is carefully integrated with its commodity work. The needs for mineral materials by industry, as well as specifications for such materials are incorporated in its commodity reports. The objective is to bring producer and user of minerals closer together with a better understanding of each others' problems of grade, processing, and pricing of the state's natural mineral and rock resources.

The Division's Bulletin 156, *Mineral Commodities of California,* published in 1950, proved so popular that it was sold out in 1953. Since then the Division has been endeavoring to compile a new revised issue of the volume and to cover the field in a more comprehensive manner. It is hoped that this new bulletin will go to press by the close of fiscal year 1955-56. The technical editing of the bulletin is the responsibility of Lauren A. Wright, while the contributions by individual commodities are planned as follows:

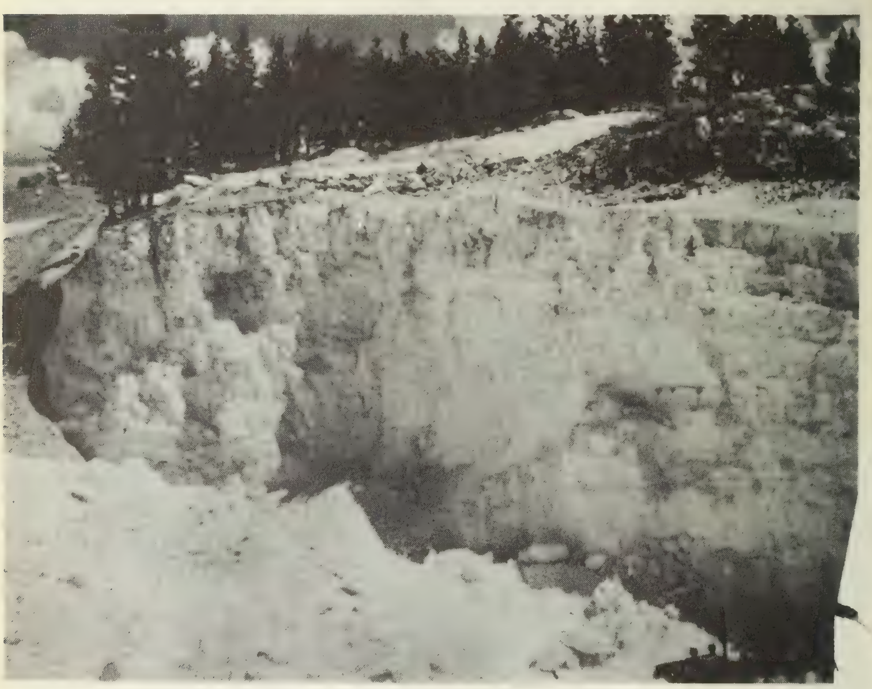

FIGURE 13. Commercial clay deposit near Casa Diablo formed by hot spri action. *Photo by George Cleveland.*

Special field studies of certain mineral commodities by members the Division's staff have already resulted in disclosing interesting fac concerning the future potential wealth of this rapidly growing stat This type of work could profitably be expanded to include many oth important commodities, if the Division had a larger technical staff, mo facilities for the work, and the necessary financial support. Some of t important current projects are summarized as follows:

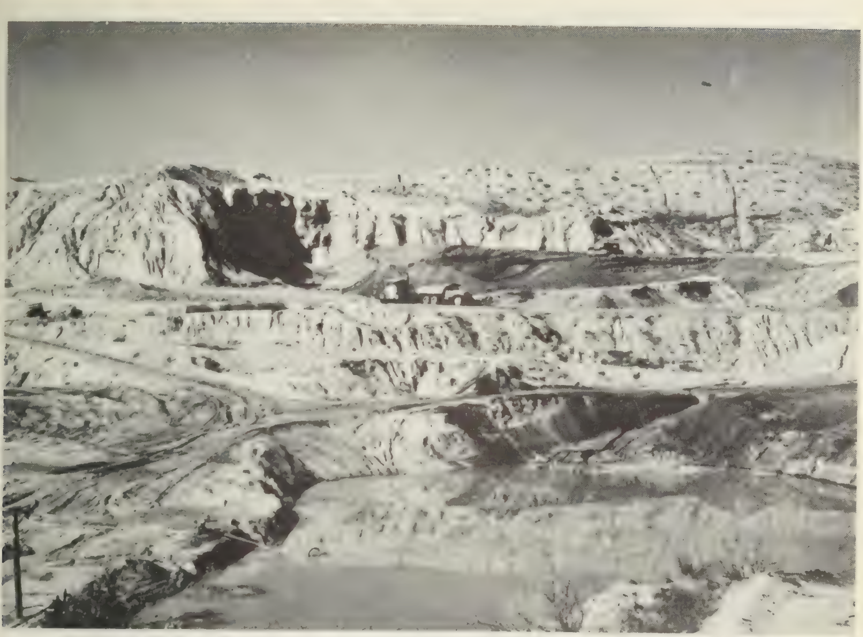

FIGURE 16. View of clay pit on property of Alberhill Coal and Clay Company, Alberhill, Riverside County. Clay-bearing formations in this area were mapped in detail by a Division of Mines staff member in fiscal 1954-55. *Photo by Burt Rogers.*

Lead	Stewart and Goodwin
Manganese	Davis
Mercury	Davis
Minor metals	Goodwin
Molybdenum	Stewart
Nickel	Rice
Platinum	Clark
Rare-earth minerals	------
Silver	Stewart and Goodwin
Thorium	Troxel
Tin	Gray
Titanium	Lydon
Tungsten	Stewart and Troxel
Uranium	Chesterman, Stinson, and Troxel
Zinc	O'Brien and Goodwin
Zirconium and hafnium	Stinson

Limestone, Dolomite, and Cement. Much interest has been shown in the Division's continuous statewide field investigations on limestone, dolomite, and cement materials, started in 1949. Several cement companies have contributed chemical analyses to the project. During this fiscal year detailed geologic studies were continued in the Sonora area of Tuolumne County and the Gabilan Peak area of San Benito and Monterey Counties. Members of the Division of Mines have examined limestone formations as well as specific deposits in over 50 of the 58 counties and have sampled deposits for chemical analyses in 20 counties. This work is supervised by O. E. Bowen, Jr., who is assisted by Cliffton H. Gray, Earl W. Hart and other members of the staff. Gray reports that the analysis data and basic information have already

ORE BUYERS' LICENSES AND INSPECTION

Public Resources Code:

"2250. It is unlawful for any person to engage in the business of milling, sampling, concentrating, reducing, refining, purchasing, or receiving for sale, ores, concentrates, or amalgams bearing gold or silver, gold dust, gold or silver bullion, nuggets, or specimens without first procuring the license provided for by this chapter.

"2253. The application for a license to carry on such business shall be made to the State Mineralogist . . .

"2267. Every licensee under this chapter shall file monthly with the State Mineralogist a report of all purchases made under this chapter. The reports shall be made upon forms prescribed by the State Mineralogist and shall contain the information required by this chapter."

Sixty-four ore buyers' licenses were issued by the Division of Mines during the year, 36 of which were limited licenses (limits buyer to $1,000 in purchases during the calendar year) and 28 of which were

FIGURE 19. The value of raw mineral materials is increased many fold by processing and manufacturing. Here clay is made into glazed Kraftile. *Photo by Mary Hill.*

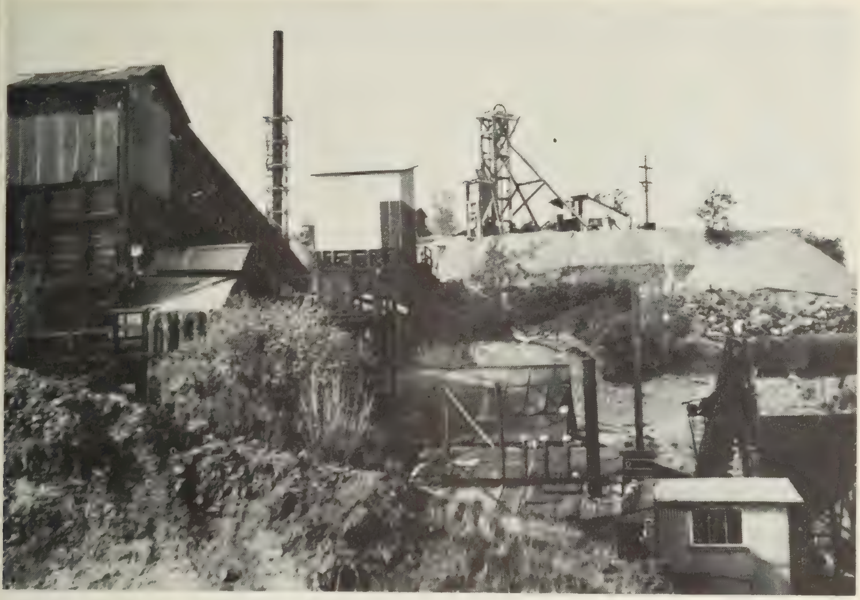

FIGURE 20. Many of the older quicksilver mines came to life during the year. Here is the Mt. Diablo mine, Contra Costa County, which was recently visited by a Division geologist. *Photo by Fenelon F. Davis.*

unlimited licenses (no limit on purchases). This does not represent much of a change over the previous fiscal year.

Licensees' records were inspected and transactions checked to insure compliance with the law. Cooperation with local, state, and federal agencies in the investigation of suspected illegal transactions and illicit traffic in gold continued during the year.

LOS ANGELES BRANCH OFFICE

Southern California possesses a diversity of minerals and rocks which is not surpassed anywhere in the world. It also contains huge markets for mineral raw materials used in its manufacturing plants. These plants are constantly increasing in size and in number. The rapid growth in population all over the state as well as in southern California is a factor of greatest consideration to investors in potential valuable mineral deposits and rocks which inevitably will become commodities of economic control in the development of the state. For this reason it is not surprising to find the Division's Los Angeles office flooded with inquiries and demands from the public for technical information. Furthermore, there are several fine institutions of learning in the south that contribute information and assistance to the work of the Division. The office, comprised of six technical (Lauren A. Wright, Richard M. Stewart, Thomas E. Gay, Jr., Bennie W. Troxel, Cliffton H. Gray, Jr., and Berdine H. Rogers) and two non-technical employees, has made much progress and accomplished outstanding achievements during the fiscal year as already outlined in this annual report. The work of this office is carefully integrated with the headquarters office and with the other branch offices in Sacramento and Redding.

In the following summary of office activities serving the public, it is apparent that the last fiscal year, 1954-55, was much more crowded with work than the previous, 1953-54:

Office Information Services

		1953-54	*1954-55*	*Percent change*
Outgoing correspondence		3,526	4,467	+27
Telephone calls		7,929	18,009	+127
Visitors		7,540	19,004	+152
Publication sales:	Total pieces	7,001	12,924*	+85
	Total value	$7,433	$17,104*	+130

* Includes sales at professional meetings in Los Angeles. These were not included in figures for previous years.

FIGURE 21. Staff member in Los Angeles branch office assisting visitor by testing rock and mineral specimens for radioactivity. *Photo by Lauren A. Wright.*

A useful library, which is steadily growing in the Los Angeles office, and a very effective mineral exhibit both serve the public as well as the staff in the study of minerals and mineral industry. During the past year, uranium seekers formed the majority of the public served.

Besides the field assignments and report writing which has been described elsewhere in this annual report, the staff members were especially active in the preparation of geologic guides published in Bulletin 170, ''Geology of southern California''; the guides have been used by many persons making excursions throughout southern California. They were prepared especially for the annual meeting of the Geological Society of America held in the fall of 1954.

A report was prepared at the request of the State Mining Board on the Saline Valley withdrawal. County reports centered principally around Kern and San Diego Counties. Geological field mapping included the Death Valley region, Shadow Mountains, Cross Mountain, Elsinore and Corona quadrangles. Special commodity investigations included talc, wollastonite, expansible shale, clay, roofing granules, limestone. Studies in the utilization of minerals in industry was continued. Staff members contributed to many technical societies and won the admiration of all the local professional groups. As a result, the Division has benefited by assistance and cooperation from geologists and engineers connected both with universities and with commercial concerns.

SACRAMENTO BRANCH OFFICE

The close proximity of the Sacramento branch office to headquarters in San Francisco makes the problem of integration of the work with the whole program of the Division quite feasible. Besides being able to use the general State Library in Sacramento, the staff members frequently come to the Division's large technical library in San Francisco and also make use of its laboratory facilities. The geographic location of the Sacramento office makes it the logical place for Mother Lode prospectors to come for information and to secure publications. During fiscal years 1954-55, uranium seekers were much in evidence. The following summary of information service rendered the public shows that activities were much greater than during the previous fiscal year.

Office Information Services

		1953-54	*1954-55*	*Percent change*
Outgoing correspondence		1,976	3,767	+91
Telephone calls		803	2,121	+164
Visitors		1,269	2,726	+115
Publication sales:	**Total pieces**	986	1,761	
	Total value	$1,207.50	$1,175.70	—3

Field activities of the two technical staff members, Denton W. Carlson and William B. Clark of the Sacramento office included county reports of San Joaquin and Sacramento Counties, both of which were published; and Calaveras and El Dorado Counties which were in progress. A report was completed on the Alleghany-Downieville lode gold mines and the recent activities along Highway 49. Studies were made of various mineral commodities in the foothills of the Sierra Nevada and special work was started on the study of vein quartz and quartzite. Staff members were particularly active in display work for the Sacramento Fair and in the meetings of local mineral and technical societies.

REDDING BRANCH OFFICE

The Redding office serves the public in answering questions, appearing before mining groups and mineral societies, and distributing the Division's publications. The following is a summary of information service rendered the public during fiscal year 1954-55, which shows a general increase over the previous year.

Office Information Services

		1953-54	*1954-55*	*Percent change*
Outgoing correspondence		973	1,185	+22
Telephone calls		444	435	—.02
Visitors		1,098	1,428	+30
Publications sales:	**Total pieces**	282	370	+31
	Total value	$290	$257	—.12

FIGURE 22. View of interior of Los Angeles branch office showing part of public information facilities. *Photo by Lauren A. Wright.*

Field activities of the Redding office, which is served by one technical employee, J. C. O'Brien, included county reports on Shasta County which was nearly completed, and Trinity County, which was started. Some mining activities were checked in Humboldt, Lassen, Plumas, Shasta, Siskiyou, and Tehama Counties. A summary commodity report was prepared on copper.

REPORT OF THE U. S. GEOLOGICAL SURVEY ON COOPERATIVE STUDIES OF MINERAL DEPOSITS IN CALIFORNIA

(Fiscal Year 1955)[1]

By Edgar H. Bailey
U. S. Geological Survey
Menlo Park, Calif.

Geological investigations of mineralized areas of California by the U. S. Geological Survey, under a cooperative agreement with the California State Division of Mines, continued during the fiscal year beginning July 1, 1954 on a slightly smaller scale than during the preceding year. The cost of the work at the field level with no supporting services amounted to about $70,000, and, as during the preceding year, the State contributed half of the cost. The gross amount of geologic work in California under other, non-cooperative, programs of the Survey, however, increased somewhat over the level of Fiscal Year 1954, and some of the results of this non-cooperative work have already been turned over to the Division of Mines for publication.

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[1] Publication authorized by the Director, U. S. Geological Survey.

During Fiscal Year 1955 no new projects were added to the cooperative program, the available funds being devoted to the furtherance of the Darwin Lead-Zinc, Bishop Tungsten, Eastern Sierra Tungsten, and Sierra Foothills Mineral Belt projects, and the supporting services of the Menlo Park Office. At no cost to the cooperative program work was continued on the final report of the East Shasta project and finishing touches were put on the Ubehebe Peak project report. These projects were on the program during previous years. The five projects receiving cooperative funds during fiscal 1955 will continue during fiscal 1956, and to them have been added the Panamint Butte and Trinity River projects. A gravity survey in the Long Valley area, Mono County, in support of the geologic mapping, is expected to yield information on the structure of the valley. The Panamint Butte project will consist of mapping the areal geology and mineral deposits of a quadrangle adjoining the Darwin project area. Gravity surveys will be made in support of the mapping in the Panamint Butte area. The Trinity River project will extend the mapping by the Geological Survey of an area of about 15,000 square miles of previously little studied terrane in the northern Coast Ranges and Klamath Mountains.

Since December 1953 the geologists working on the California cooperative program have been stationed at the western headquarters of the Geological Survey in Menlo Park along with about 70 other Survey geologists. The benefits of being in this major research center are being increasingly felt by the geologists on the cooperative program and are reflected in the quality of their work and the facility with which it is completed. The availability of well equipped laboratories specifically designed for chemical, petrographic, and x-ray research has enabled the geologists to determine more readily and with greater precision the mineral content of the ores and rocks found in the project areas. In addition, they are profiting by the mutual exchange of ideas among the large group of Survey geologists assigned to working on a variety of projects in the western United States.

Sierra Foothills Mineral Belt

The Sierra Foothills mineral belt, which has an area of over 6,000 square miles, extends along the western flank of the Sierra Nevada batholith for a distance of about 200 miles, and includes the Mother Lode gold belt, the so-called East gold belt, and the Foothill copper belt. Although the production of gold from the Mother Lode has been of immense historic and economic significance, many other mineral commodities have been mined in the area. The other important production includes over 200 million pounds of copper, 50 million pounds of zinc, 88,000 tons of chromite, and millions of dollars worth of cement. Current mining interest is shown by the expanding production of lime products, active exploration of copper-zinc-lead and tungsten deposits, and continued production from several gold lodes.

The purpose of the Sierra Foothills project is to achieve most rapidly and at least cost an understanding of the stratigraphic and structural relationships along the entire mineral belt. When these relationships have been established, existing geologic maps can be reinterpreted to yield much new information at a fraction of the cost of remapping the area on a large scale. The existing maps of the mineral belt reveal alternating linear bands of sedimentary and volcanic rocks that extend parallel to the Sierra Nevada front, but only locally have the structural relationships of these rocks been clearly established. As the structural and stratigraphic relationships are major factors in the localization of the valuable mineral commodities that have been mined, we believe the clarification of the structural and stratigraphic relations will provide a firmer approach to the reasons for the localization of the known ore bodies and should lead to new ideas as to where undiscovered ore should be sought.

The first phase of the field work, the detailed mapping of the valleys of the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes Rivers, was essentially completed by the end of Fiscal Year 1954, although spot checks and short traverses in places previously inaccessible because of high water made during the Fall of Fiscal 1955. The only other field work done during the past year consisted of a trip to Mariposa County to collect fossil plesiosaur bones from a new locality that had been discovered by Survey geologists the previous spring. Most of the year was spent on office and laboratory work, and much was accomplished on the preparation of the report entitled ''Stratigraphic and structural relationships in part of the western Sierra Nevada Foothills,'' and on the compilation of a geologic map of the San Andreas 15′ quadrangle that will be included in that report. Structure sections along the major rivers have been prepared and considerable petrographic work was done on rocks belonging to the western block of the Calaveras formation, the Amador group, the Mariposa formation, and the Gopher Ridge volcanics sequence.

Among the more significant accomplishments to date are the preparation of a block diagram showing structural features of the area, and the gathering of evidence suggesting that movement on at least some of the major faults in the Foothill Belt had a large strike-slip component. The project geologist presented at the Geological Society of America meetings a paper on ''A geologic cross section of the western Sierra Nevada foothills,'' outlining some of the results of the work to date.

Bishop Tungsten

The Bishop Tungsten District in northern Inyo County contains some of the most productive tungsten deposits in the United States. The mapping of the areal geology and mines in the 800 square mile project area, which embraces all of the Mt. Tom, Bishop, and Big Pine 15-minute quadrangles and a part of the Mt. Goddard 15-minute quadrangle, was completed in 1950. Fiscal Year 1955 saw the completion and transmittal to the California State Division of Mines for publication, of a 292-page report entitled ''Economic geology of the Bishop Tungsten District.'' This report, containing 55 illustrations, many of which are detailed mine maps, emphasizes features that have direct bearing on the discovery and exploitation of the mineral deposits and is directed primarily to the economic geologist, mining engineer, miner, and prospector. A second report, now in preparation, is planned for publication as a U. S. Geological Survey Professional Paper, and is directed to professional geologists as well as other scientists and interested laymen. It will contain detailed descriptions of the rocks and structures in the area and a discussion of a variety of scientific problems in addition to those directly related to the deposition of the tungsten ores. Among these are the constitution, age, and origin of a large sample of the Sierra Nevada batholith and the interesting structures present in the thermally metamorphosed rocks of the roof pendants and the dynamically metamorphosed sedimentary rocks of the White Mountains. Other sections of this report are devoted to the structural development of Owens and Round Valleys and to the evolution of the landscape.

Eastern Sierra Tungsten

The project area includes five 15-minute quadrangles north and west of the Bishop Tungsten District. Within it are active tungsten mines and unexploited deposits of tungsten, gold, silver, copper, lead, zinc, and iron, as well as deposits of kaolinite clay, perlite, pumice, and sand and gravel. The area is being mapped on a quadrangle basis, and reports are being prepared for each quandrangle as the mapping is completed. During Fiscal Year 1954 the mapping of the Casa Diablo Mountain quandrangle was finished, and during Fiscal Year 1955 two manuscripts dealing with the geology and ore deposits were prepared; one of these, an economic report, has been transmitted to the California State Division of Mines for publication, and the other is a Quadrangle Map Series report to be published by the Geological Survey. Also during Fiscal Year 1955 field work in the Mount Morrison (formerly Mount Morgan) quadrangle was completed, and a manuscript geologic map showing the relation of mineral deposits to the regional structure and rock distribution, as well as detailed large scale geologic maps of the accessible workings of all mines in the quadrangle, was prepared. The writing of the text of the report on the Mount Morrison quadrangle was about half finished at the close of the fiscal year.

Mapping in the Mount Morrison quadrangle has delineated in the Sierra Nevada batholith a moderate-sized roof pendant which consists of nearly 30,000 feet of slightly metamorphosed sedimentary rocks ranging in age from Ordovician to Pennsylvanian, as indicated by the fossils discovered by the project geologists. This sequence, hitherto undescribed, has been subdivided into 12 formations, which are being described in detail, and it provided the basis for a paper entitled ''Paleozoic section in the eastern Sierra Nevada, Mono County, California,'' presented at the annual meeting of the Geological Society of America. It is interesting to note that the Ordovician rocks closely resemble rocks of the same age included in the ''western facies'' sedimentary sequences exposed in western Nevada.

Darwin Lead-Zinc

The geologic mapping of the Darwin quadrangle, an area of notable mineral wealth where little geologic work has been done in the past, was completed during Fiscal Year 1954. During Fiscal Year 1955 additional field work was done to complete the detailed mapping of some of the smaller mines, to map previously inacessible workings in the larger mines, and to test the applicability of geochemical prospecting in the Darwin area. Upon transmittal of the two main reports, an economic report, which is being reviewed and processed for publication by the State Division of Mines, and a U. S. Geological Survey Bulletin, now partly prepared—the Darwin project will be terminated. The geologic mapping of the Panamint Butte quadrangle, which is adjacent to

Darwin and in reality an extension of the Darwin work, has been started under the direction of the geologist who served as project chief of the Darwin project.

The economic report already prepared includes a comprehensive description of the geology and ore controls for the highly productive Darwin lead-zinc mine, a description of about twenty smaller lead-zinc mines, a discussion of eleven tungsten deposits, one antimony deposit, several copper deposits, and about a dozen talc deposits, including the largest steatite-talc producer in the State. In addition, it briefly describes a nearly complete section of Paleozoic sedimentary rocks ranging in age from Ordovician to Permian, and discusses the character of the granitic rocks intruded during Cretaceous time and the Upper Tertiary volcanic rocks of the area. Part of the results of the cooperative study of the Darwin quadrangle were reported in a pair of papers presented at the Cordilleran Section of the Geological Society of America during April, 1955.

Office Activities

At the end of the fiscal year in addition to the District Supervisor and his assistant, the office staff consisted of three draftsmen, a chief clerk, an accounting clerk, a manuscript typist, and four clerk typists. This staff serves a large group of geologists headquartered at Menlo Park and only a small part of the office expense is borne by the cooperative program. During the Fiscal Year 15 reports pertaining to California geology were handled by the District Office. Of these, 7 manuscripts containing 810 pages and 171 illustrations, chiefly maps, resulted directly or indirectly from the cooperative program. During the year 6 manuscripts totalling 797 pages and 134 illustrations were transmitted to the State Division of Mines for publication.

Other Contributions to California Geology

Considerable geologic work is carried on by the U. S. Geological Survey in California on projects not a part of the cooperative program. Some of the results of this work are published by the Division of Mines and others by the Geological Survey. One immediately useful product prepared outside of the cooperative program last year was a report on occurrences of radioactive minerals in California. This was transmitted to the California State Division of Mines for publication and upon its release will provide needed information to the thousands of Californians interested in prospecting for uranium.

To assist the Division of Mines in the preparation of its new geologic map of the State, geologists working on cooperative projects have contributed both lithologic and structural information. Other Survey geologists working on non-cooperative projects, notably in the desert regions and northwestern California, also have contributed data for this map.

As in several previous years Survey geologists have participated in the examination of mines and mineral properties for the Defense Minerals Exploration Administration. California falls under DMEA's Region II, and the geologist in charge of the Survey's activity in Region II is stationed at the Menlo Park headquarters where he is assisted by two other geologists, a clerk-typist, and a draftsman. In addition to keeping abreast of recent developments in the California mineral industry, the DMEA staff made a total of 37 examinations in the State in response to formal applications from miners and prospectors for Government assistance in exploration. Of these examinations 15 were on tungsten properties, 5 quicksilver, 6 uranium, 4 chrome, 1 manganese, 1 copper-zinc, 1 copper-lead-zinc, 2 lead-zinc, and 2 copper. Nine new contracts were awarded during the year, and the total value of the 14 contracts in effect as of June 30, 1955 was approximately $1,260,000.

An ''extracurricular'' event to both Survey and the Division of Mines was the participation in the national meeting of the Geological Society of America held in Los Angeles in November 1954. The release of parts of the Division of Mines' Bulletin 170, *Geology of Southern California,* coincided with the meeting. Survey geologists contributed papers and maps to this Bulletin and the drafting staff at Menlo Park prepared a number of the illustrations. One of the field trips was led by a Survey geologist. The Guidebook, meeting, and field trips were all useful in acquainting professional geologists from all parts of the country with the nature and problems of California geology.

SAND AND GRAVEL FOR CONCRETE AGGREGATE

By Harold B. Goldman*

OUTLINE OF REPORT

	Page
Abstract	79
Introduction	79
Sources of aggregate	81
Stream deposits	81
Sand and gravel from dredge operations	85
Talus deposits	87
Glacial deposits	87
Mine dumps and tailings	88
Marine sand and gravel	88
Pre-Quaternary formations	89
General requirements of aggregates	90
Field phase of selection of materials	91
Laboratory phase of selection and control of materials	93
Laboratory test methods of determining aggregate suitability	95
General specifications	100
Methods of improving quality of aggregate	101
References	103
Selected references on alkali-aggregate reactivity	104

Illustrations

	Page
Figure 1. Sketch map showing rock types along Colorado River	80
2. Diagram showing transportation and deposition of marked sands	82
3. Photo showing floodplain deposit	83
4. Photo showing alluvial fan deposit	84
5. Plan of abandoned stream channels and present stream channel in alluvial fan	84
6. Idealized sketch showing types of alluvial deposits	85
7. Photo showing old dredge tailings	86
8. Photo showing talus of granitic rock	87
9. Photo showing typical glacial debris	88
10. Photo showing dump at Kennedy mine, Jackson Gate, Amador County	89
11. Photo showing typical conglomerate	90
12. Photo showing petrographer examining aggregate material	94
13. Photo showing Los Angeles rattler	95
14. Photo showing mechanical shaker	98
15. Photo showing Ro-Tap sieve shaker	98
16. Photo showing sand equivalent test	99

ABSTRACT

The investigation of rock, sand and gravel for use as concrete aggregate is a complex undertaking involving both field and laboratory studies. Preliminary geologic field investigation of a deposit to ascertain the presence of deleterious materials such as physically unsound or chemically reactive rock is an important phase of aggregate evaluation. Subsequent laboratory tests to substantiate preliminary observations must also be employed. Many routine physical tests are used to evaluate properties such as abrasion resistance, soundness, specific gravity, absorption and grading. Specialized tests are employed to detect chemically reactive ingredients. In some areas deposits are beneficiated to meet certain minimum specifications using various techniques.

INTRODUCTION

The term aggregate is commonly applied to the inert fragmental material which is bound into a conglomerate mass by a cementing material such as portland cement, asphalt, or gypsum plaster. Technical

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* Mining geologist, California Division of Mines. Manuscript submitted for publication October 1955.

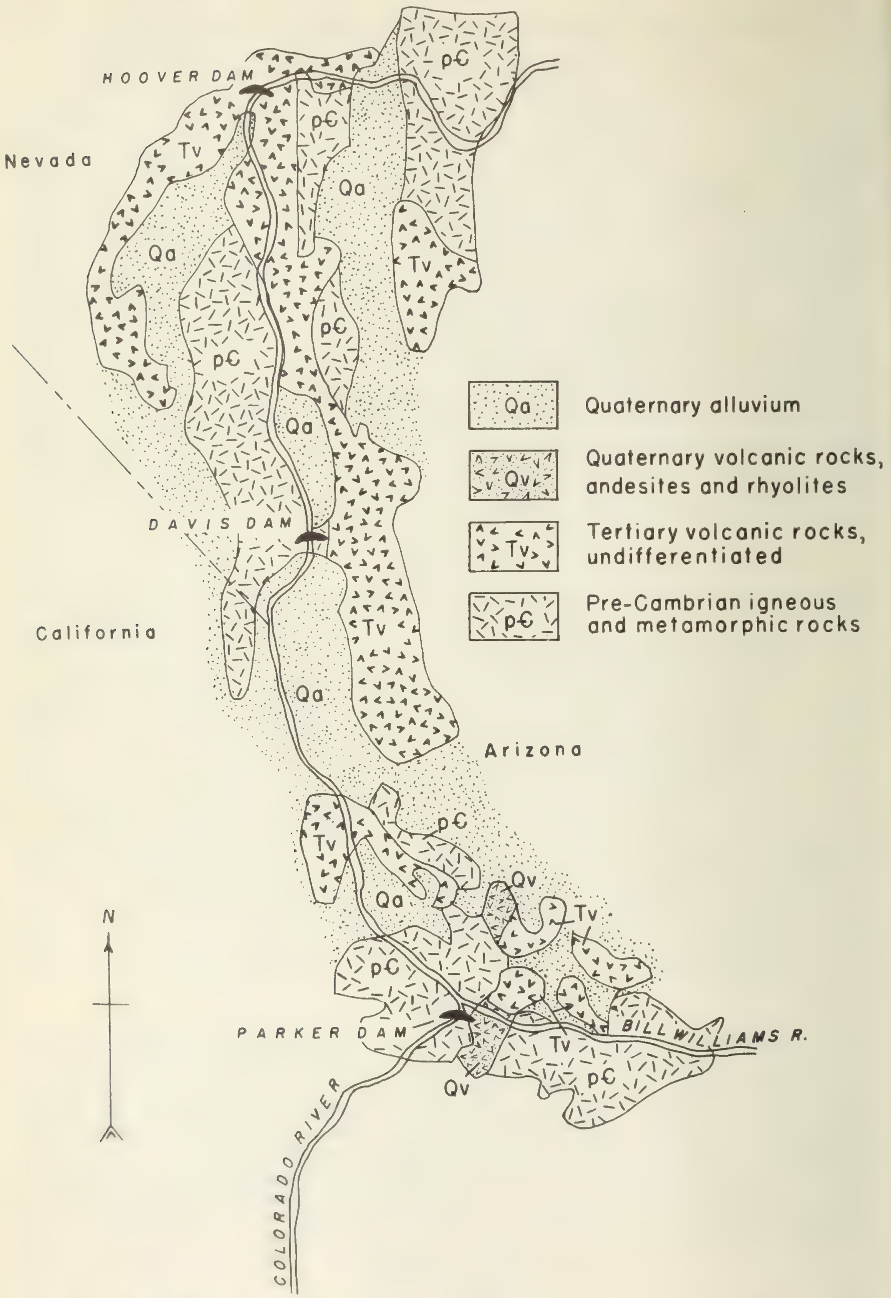
HOOVER DAM
Nevada
DAVIS DAM
California
Arizona
PARKER DAM
BILL WILLIAMS R.
COLORADO RIVER
N
Qa
Tv
pC
Qv
Qa Quaternary alluvium
Qv Quaternary volcanic rocks, andesites and rhyolites
Tv Tertiary volcanic rocks, undifferentiated
pC Pre-Cambrian igneous and metamorphic rocks

FIGURE 1. Sketch map showing distribution of rock types along the Colorado River from Hoover to Parker Dam. *From U. S. Geological Survey, Geologic map of United States.*

studies indicate that aggregate materials rarely are completely inert, either chemically or physically. Premature deterioration of concrete has been traced in many instances to the use of unsuitable aggregate. This discussion is concerned with the nature and determination of the chemical and physical properties of rock, sand and gravel which affect their use as aggregate in portland cement concrete.

Much of the material used in the discussion was synthesized from these excellent sources: The Concrete Manual, a publication of the U. S. Bureau of Reclamation; the Standards of the American Society for Testing Materials; and the papers by Richard C. Mielenz, Elliot P. Rexford, and Roger Rhoades that are listed in the references.

SOURCES OF AGGREGATE

Aggregate materials have been obtained commercially from rock units of many types and ages. Quaternary stream deposits in channels, terraces, flood-plains and alluvial fans, and marine sands and gravels are the most common sources. In some areas aggregate is obtained from pre-Quaternary formations including Tertiary and Mesozoic sedimentary rocks, and is even quarried from bodies of pre-Tertiary crystalline rocks. Talus deposits, glacial deposits and mine tailings are of interest as potential sources.

Stream Deposits

Most of California's aggregate production is obtained from natural sand and gravel in stream deposits. California's rugged mountains are drained by streams with steep gradients which, in flood stage, transport huge volumes of sand and gravel.

Deposits in Stream Channels. Stream channel deposits consist of sand and gravel deposited in stream beds and as bars along the present stream course. Channel deposits are widely exploited since the streams are dry a large part of the year and deposits are readily accessible and easily mined. Materials in these deposits are desirable as aggregate for many reasons. The natural abrasive action of stream transport has ground up and removed most of the soft weak rocks and concentrated the harder and firmer particles. The particles have undergone some degree of rounding and in some streams, such as the American River near Sacramento, are well-rounded. This is an important factor since concrete made with rounded particles requires less cement and care than concrete made with angular fragments.

Channel deposits normally are free of excessive amounts of silt and clay and most deposits contain sand and gravel in the size gradations necessary for concrete design. Mining operations are often relatively simple, consisting of no more than washing and screening to obtain suitable aggregate. In spite of these qualities some deposits are unsuitable because they contain harmful ingredients such as physically unsound or chemically reactive rocks. The nature of the material in the stream channel is determined in a large part by the nature of the source rocks within its drainage area. Different geological formations in a drainage basin contribute a variety of rock types which show a wide range in chemical composition and degree of weathering.

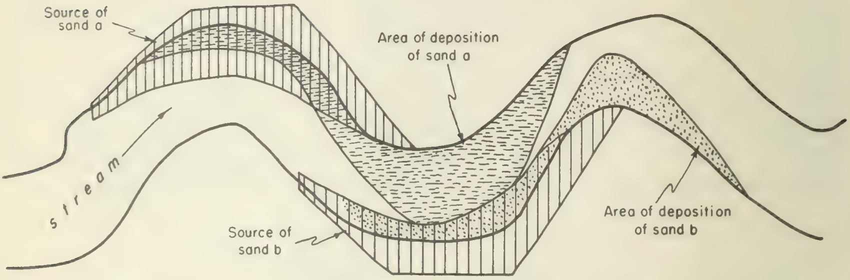

FIGURE 2. Transportation and deposition of marked sands in a stream in a laboratory experiment by the U. S. Waterways Experiment Station, 1945. *From Gilluly, J., et al., Principles of Geology, p. 259.*

An example of the influence of source rocks on the quality of materials in stream deposits is provided by the Colorado River between Hoover and Parker Dams (Rhoades, 1950, p. 443). The Colorado River in the vicinity of Hoover Dam contains a complex assemblage of rock types of which only a small proportion are chemically reactive. Hoover Dam concrete made with this aggregate shows no sign of harmful chemical reactivity after 20 years of service. Below Hoover Dam the Colorado River flows over predominantly volcanic rocks and the content of reactive volcanic rock increases progressively downstream.

At Davis Dam, 67 miles below Hoover Dam, the content of reactive ingredients increases to the point where it was unwise to use the aggregate unless special precautionary measures to forestall alkali-aggregate reaction were taken. Farther downsteam, the tributary Bill Williams River contributes large amounts of highly reactive andesites and rhyolites to the main stream. Parker Dam built with this aggregate exhibited signs of alkali-aggregate reaction within 2 years after completion (Merriam, 1953, p. 7).

Stream Terraces. Stream terrace deposits are benchlike deposits of sand and gravel which border a stream but lie above the level of the present flood plain. These deposits are remnants of older flood plains through which the stream has cut. Terrace deposits because of a higher topographic position may be more desirable than stream channel deposits in areas where shallow water table conditions present operating difficulties. The materials in these deposits have the general properties of stream channel material and are also widely used for aggregate. For instance, the terrace deposits on the north bank of the Stanislaus River in San Joaquin county have been exploited successfully for sand and gravel for nearly 40 years (Clark, 1955, p. 61). However, not all terrace deposits can be used for aggregate. Some deposits are only thin veneers of sand and gravel deposited on a stream-cut bedrock surface. The materials in the deposit may not be suitable if they have undergone post-depositional weathering or if the grains have become coated with harmful substances due to the action of ground waters. Some portions of the Quaternary terraces of the Kern River near Bakersfield, for example, are unsuitable because of the presence of reactive opaline coatings associated with calcium carbonate incrustation on the pebbles (Klein 1950, unpublished report).

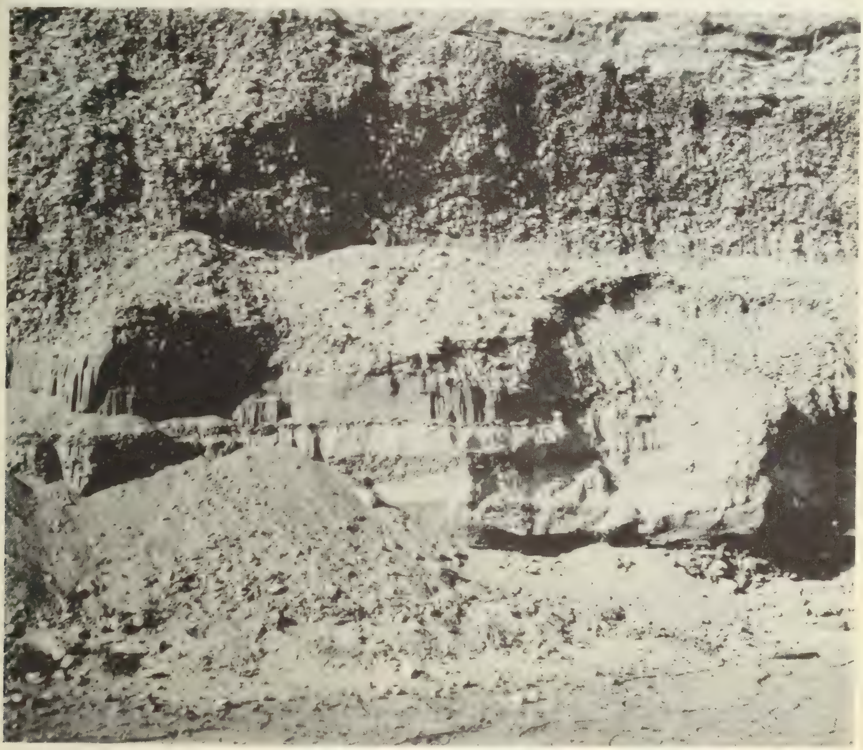

FIGURE 3. Floodplain deposit laid down by frequently shifting stream. The deposit is characteristically heterogeneous, containing lenticular sand members. *Photo by Thomas E. Gay Jr.*

Floodplain Deposits. True floodplain deposits consist of the material deposited on plains bordering a stream by periodic overflow of the streams from their channels. The sediments deposited are normally composed of silt and sand grains. However, these fine materials often mantle usable deposits of sand and gravel. These buried deposits occur in elongate lenses representing the courses of former stream channels. The materials in these deposits have the general character of channel and terrace deposits and where the necessary grading can be obtained are also suitable for aggregate.

Alluvial Fans. An alluvial fan is a gently sloping fan-shaped mass of loose rock material deposited at the mouth of a canyon where a stream leaves the mountains and enters an adjacent valley or plain. The abrupt flattening of gradient causes deposition of the bulk of the bed load in a crudely stratified mass. The coarser material, cobbles and boulders, is deposited at the apex of the fan and the average grain size decreases toward the base of the fan. Fan deposits ordinarily contain lenticular beds or tongues of poorly sorted sand and gravel interbedded

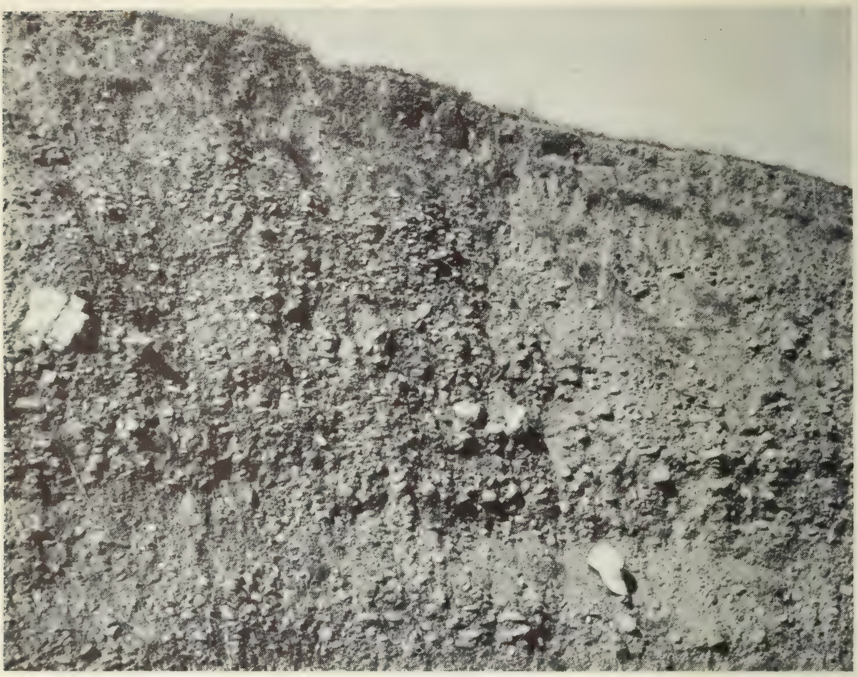

FIGURE 4. Alluvial fan deposit of Corral Hollow Creek, San Joaquin County. Crude stratification is due to alternating layers of gravel and sand. *Photo by William B. Clark.*

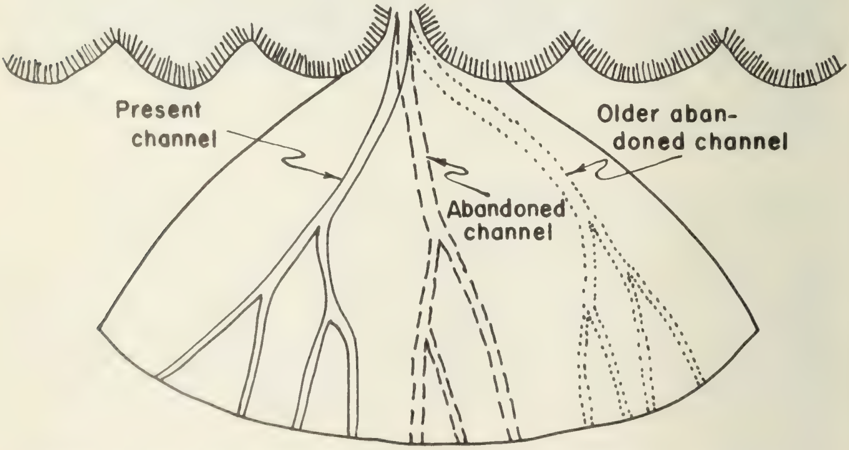
Present channel
Older abandoned channel
Abandoned channel

FIGURE 5. Plan of abandoned stream channels and present channel of stream in an alluvial fan. *After Tolman, C. F., Ground Water, p. 369.*

with varying proportions of silt and clay, and therefore require more processing than stream channel deposits. Suitable aggregate is obtained from fan deposits in areas where the proportion of clay is not so great that expensive beneficiation is necessary. An alluvial fan that is a major source of aggregate is that of Alameda Creek, near Niles, Alameda County, which is now providing much of the aggregate for the San Francisco Bay area. There the commercial deposits contain unconsolidated, crudely stratified, sub-angular sands and gravels which are mined to depths of 100-150 feet. The thickness of the deposit has not been determined although it is reported that a well was drilled to 1,000 feet in alluvial material (Davis, 1950, p. 334).

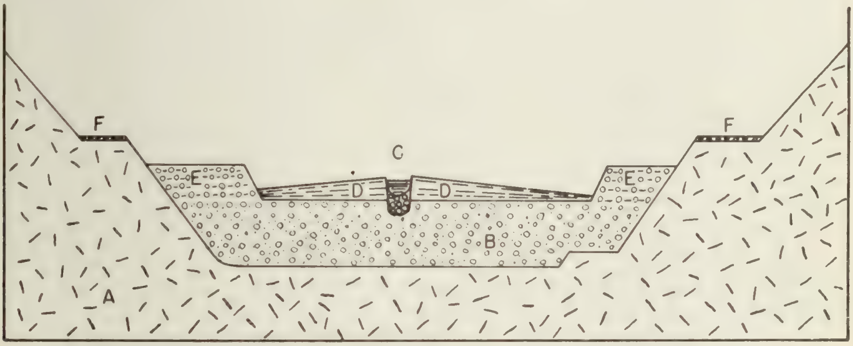

FIGURE 6. Idealized sketch showing types of alluvial deposits. *A*, Bedrock. *B*, Older alluvial deposit of sand and gravel. *C*, Gravel of present stream channel. *D*, Silt and clay of floodplain deposit. *E*, Stream terrace cut in older alluvium. *F*, Thin veneer of sand and gravel on a stream-cut bedrock terrace.

Sand and Gravel from Dredge Operations

As a result of bucket dredge operations for gold, huge furrowlike ridges of gravels have been accumulated as tailings along many of the streams in the Sierra Nevada foothills. A normal gold-dredging operation involves washing and screening the stream deposit. The oversize gravel, which ordinarily consists of everything over ½ or ¾ inch, is washed and sent to tailing piles behind or alongside the dredge. The undersize fine gravel and sand are then processed to remove the gold and returned to the dredge pond and subsequently covered by other oversize tailings. This results in segregated deposits of fine gravel and sand which underlie coarser gravels, requiring that considerable material be processed by aggregate producers to obtain the desired gradings of sand and gravel. Most commercial operations employ equipment to crush the oversize tailings. Tailing piles which have not been subjected to excessive weathering contain material as suitable as the related stream deposit.

Some of the localities where old dredge tailings are being used for aggregate are in Butte County along Butte Creek near Chico and along the Feather River near Oroville. The tailings there are composed of 18-25 feet of coarse gravel which overlie the sand. Most production is from this upper layer which is used largely as a source of crushed rock for railroad ballast and road-base mixtures (O'Brien, 1949, pp. 435-437).

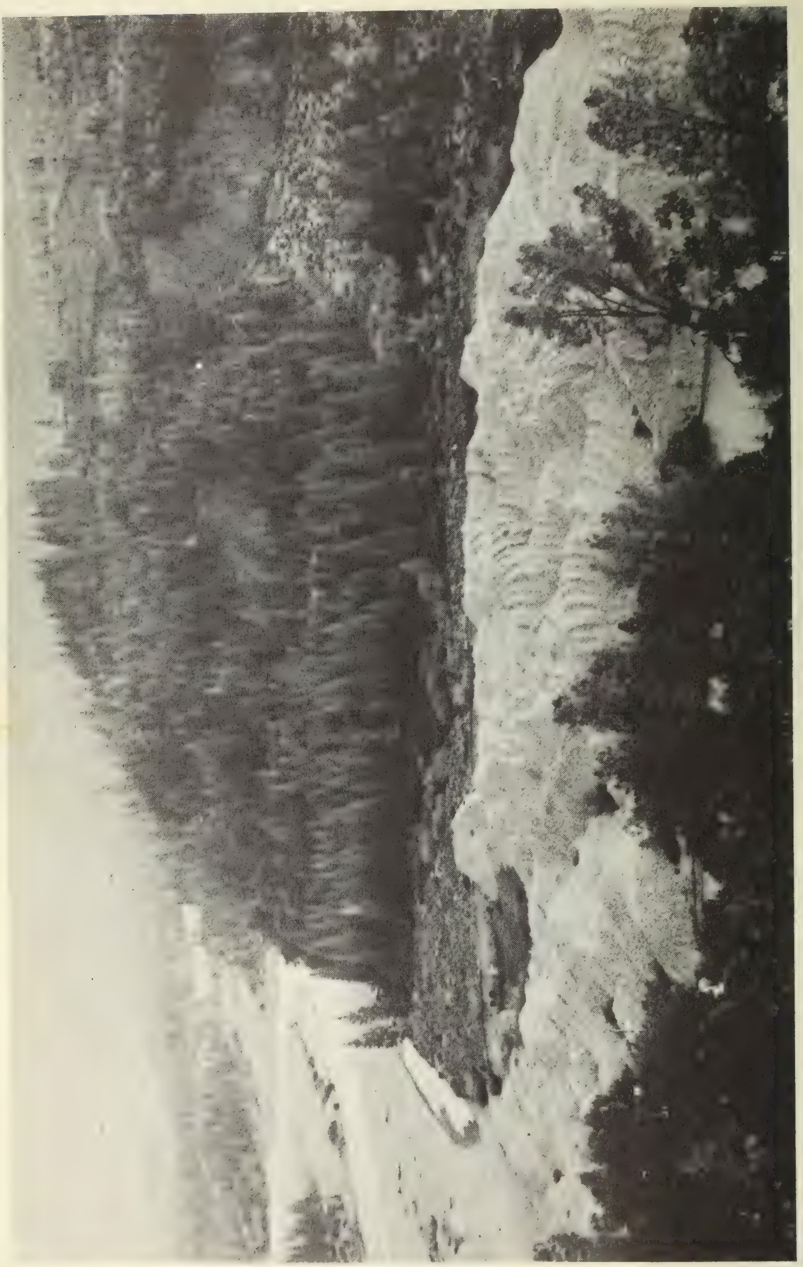

FIGURE 7. Old dredge tailings in the bed of the Trinity River at Junction City. The normal stream channel deposits of sand and gravel are seen in the extreme left portion of the picture. *Photo by Olaf P. Jenkins.*

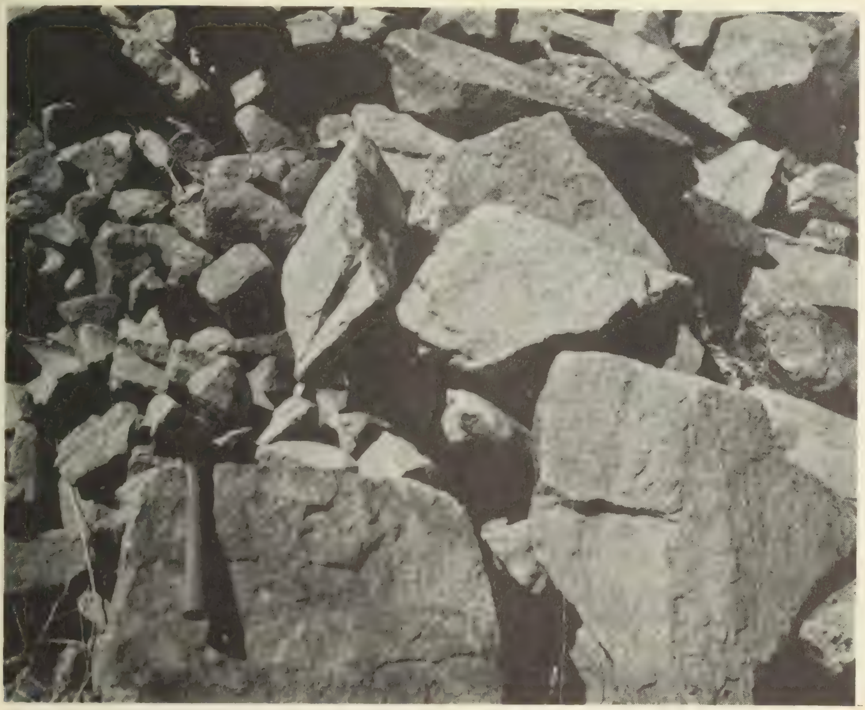

FIGURE 8. Talus accumulation of granitic rock in the Sierra Nevada, showing blocky character and size variation of the fallen and broken rock. *Photo by Mary Hill.*

Talus Deposits

Talus accumulations form at the bottoms of steep slopes by the falling of loosened rock. Such deposits are usually composed of a single rock type whose fragments are angular and show a wide range in size and shape. Talus deposits may be processed as aggregate if the parent rock possesses characteristics suitable for concrete aggregate. Crushing and other beneficiation normally applied to quarried rock may be required. At present, no talus deposits in California are yielding commercial aggregate.

Glacial Deposits

Glacial deposits in California are restricted to high elevations and are lacking in portions of the state. Glacial deposits, such as glacial moraines which have been transported solely by glacial ice, contain materials which have not been subjected to the abrasive action of streams. These deposits usually contain materials of diverse size, shape, and quality, ranging from rock flour to erratic boulders, and are usable only after expensive processing. Fluvial-glacial deposits are glacial materials that have been subjected to stream action and are deposited in stream channels or on outwash plains. Only moderate reworking of true glacial deposits by streams may suffice to form deposits that yield satisfactory aggregate materials comparable to true stream sands and gravels (Rhoades, 1950, p. 454).

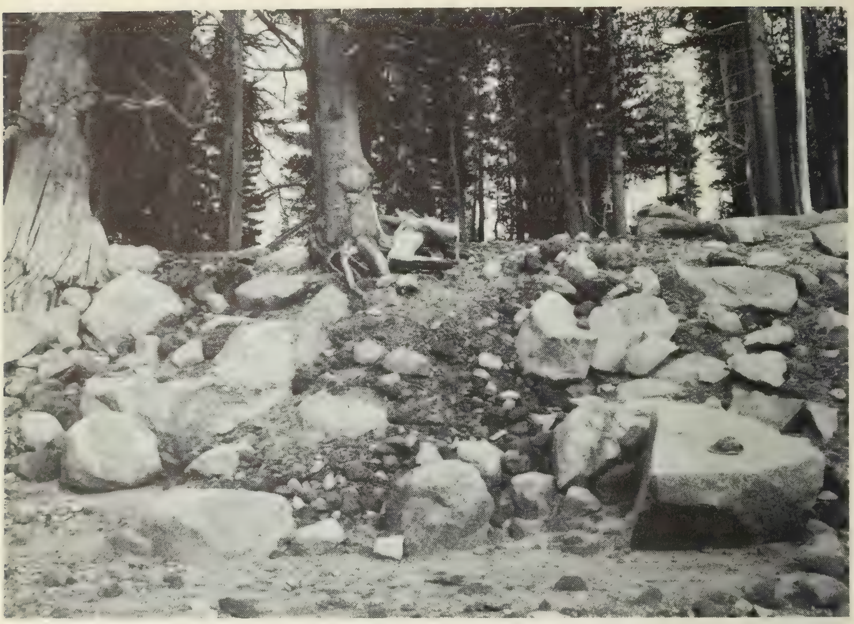

FIGURE 9. Typical deposit of glacial rock debris (till) in the high areas of the Sierra Nevada. This heterogeneous accumulation contains particles ranging in size from fine sand to large boulders. *Photo by Mary Hill.*

Mine Dumps and Tailings

As a result of mining operations, large dumps of crushed rock have been accumulated in California, particularly in the Mother Lode country of the Sierra Nevada. These dumps, used for common road-base materials, are generally unsuitable for concrete aggregates because they lack the proper size and gradation, and contain harmful minerals such as sulfides. Conceivably tailings from milling operations composed predominantly of quartz could be processed for silica sand.

Marine Sand and Gravel

Sands and gravels formed by the winnowing action of currents and waves on a beach make excellent aggregate. Particles are generally well-rounded, hard and firm, and occur in narrow size ranges. The sands are commonly composed of resistant quartz and feldspar. Most beach deposits, however, are thin, lack proper size gradation, or are too inaccessible to be utilized for aggregate. Harmful salts may impregnate the material so that vigorous washing would be required during processing.

Beach and near-shore dune sand deposits yield about 2 percent of the total sand and gravel produced in California. The deposits consist almost exclusively of sand which is used as concrete and plaster sand or in special instances as glass, sandblasting, or foundry sand (Wright, 1948, pp. 37-72). Some coarse aggregate is produced from the Pleistocene marine San Pedro formation near Lomita in Los Angeles County. The formation there contains about 10 percent gravels up to 1 inch and 90 percent sand or finer material (Gay and Hoffman, 1954, p. 542).

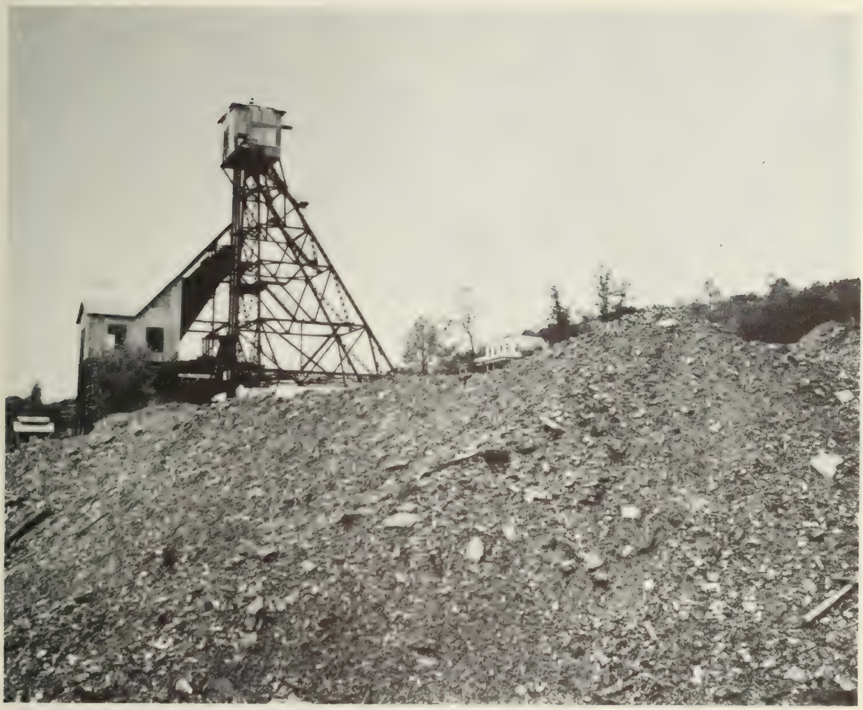

FIGURE 10. Mine dump of the Kennedy mine, Jackson Gate, Amador County. Similar dumps in the foothills of the Sierra Nevada are used as local sources of common fill rock. *Photo by Mary Hill.*

Pre-Quaternary Formations

Pre-Quaternary formations particularly partly consolidated sedimentary beds of sandstone and conglomerate afford usable sources of aggregate when post-depositional weathering has not been too complete. Ordinarily, these formations have been subjected to long periods of weathering and are either too well cemented or contain too much clayey material to be processed economically. Accessibility of the deposit and depth of overburden also present problems. Among the pre-Quaternary formations which are being mined in California are the Novato conglomerate of Cretaceous(?) age in Marin County and the upper Miocene Santa Margarita formation in Santa Cruz County.

The Novato conglomerate is a crudely stratified, poorly consolidated deposit of well-rounded pebbles and cobbles in a sandy clay matrix. The deeply weathered gravels are removed by an impact crusher while the sands are treated by attrition machines. Suitable aggregate is produced from this formation near Blackpoint (Ver Planck, 1955, pp. 239-242).

Concrete sands are produced from the Santa Margarita formation near Felton. The deposits consist of massive, well-sorted, poorly indurated sandstones with occasional interbedded thin conglomerate beds (Hubbard, 1943, p. 51).

The pre-Quaternary formations which are composed of well-indurated sedimentary rocks or hard crystalline rocks require expensive quarrying

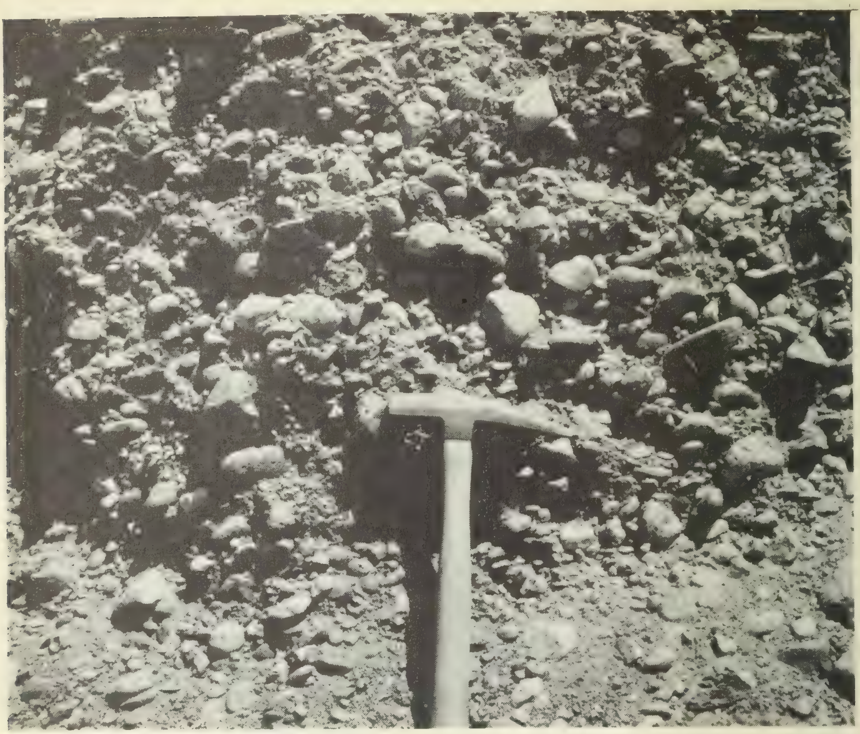

FIGURE 11. Typical conglomerate. The gravel is bound by a fine-grained clayey sand matrix. *Photo by Mary Hill.*

operations to obtain suitable material for aggregate. Quarrying rock outcrop has some advantage over developing stream deposits in that once the physical and chemical characteristics of the rock are established, production can proceed without the danger of encountering harmful ingredients. Production can be closely controlled in all grade sizes. However, quarrying operations and the use and maintenance of crushing equipment are expensive compared with the production costs for unconsolidated materials. The resultant aggregate is harsh and angular, requires more cement for concrete and is harder to work than rounded grains. Most crushed rock goes into bituminous road base mixtures where the angular shape is desirable to provide greater stability under load.

GENERAL REQUIREMENTS OF AGGREGATES

A suitable aggregate has many requirements that are difficult to meet if only unprocessed material from natural deposits is used. Suitable material is composed of clean, uncoated, properly shaped particles which are sound and durable. Soundness and durability are terms used to denote the ability of aggregates to retain a uniform physical and chemical state over a long period of time so as not to cause disruption of the concrete when exposed to weathering and other destructive processes. To have these attributes, individual particles must be tough and firm, possessing the strength to resist stresses and chemical and physical changes such as swelling, cracking, softening and leaching. The aggregate should not be contaminated by much clayey material, silt, mica, organic matter, chemical salts and surface coatings.

The requirements for the commercial exploitation of suitable aggregates, such as available volume of materials, water supply, transportation, proximity to market, and zoning restrictions are assumed to have been satisfied in the ensuing discussion.

The selection and control of suitable materials is a two-fold problem involving a field phase and a laboratory phase.

Field Phase of Selection of Materials

Preliminary field evaluation by a geologist or by an engineer with some geologic training may often suffice to evaluate a deposit as a possible source of aggregate material. The characteristics that bear upon the usefulness of a deposit as a source of aggregate material have been determined by the geologic processes by which the deposit was formed and subsequently modified. A basic understanding of the processes, therefore, is helpful to the person evaluating it. The important characteristics are types and physical condition of the rock, grading, rounding and degree of uniformity, size, shape and location, thickness and type of overburden, and ground water level (U. S. Bureau of Reclamation, 1955, p. 75).

By the judicious use of geologic maps a geologist can determine the type of materials to be encountered in a certain drainage area and predict the type of alluvial material to be found in a given stream channel. He can thereby recognize likely sources of aggregate and can often rule out areas unlikely to contain suitable materials. The geologist uses commercial sand and gravel deposits as a yard stick to guide him in evaluating new deposits. By comparing service records and laboratory test results with the petrographic character of commercially proven aggregates, the geologist builds up a background of data from which he can extrapolate to predict the behavior of untested deposits of similar petrographic character. This technique has been used successfully by the U. S. Bureau of Reclamation in preliminary planning studies for large structures that require large amounts of suitable aggregates. In many instances field evaluation has obviated the need of expensive and time consuming laboratory tests.

Factors in Field Evaluation of Deposits

The quality of aggregate depends upon its physical and chemical properties. These in turn may be inherent mineralogical and textural features of the rock or may be the effects of later changes such as tectonic fracturing, mechanical or chemical weathering, or incrustations.

The physical properties most significant with regard to concrete are: 1) abundance and nature of fractures and pores, 2) particle shape and surface texture and 3) presence of material which may cause volume change (Mielenz, 1946, p. 310). An aggregate is considered to be physically sound if it is adequately strong and capable of resisting the agencies of weathering without disruption or decomposition. Minerals or rock particles that are physically weak, extremely absorptive and easily cleavable are susceptible to breakdown by weathering. The use of such materials in concrete reduces strength or leads to early deterioration by promoting weak bond between cement and aggregate, or by inducing cracking, spalling or pop-outs (U. S. Bureau of Reclamation 1955, p. 51). Severely weathered, soft, micaceous or porous materials may cause localized stresses to develop in concrete by swelling and shrinking during wetting and drying or freezing and thawing cycles.

Suitability of the Various Rock Types. Sedimentary rocks show a wide range in physical qualities and suitability. Sandstones and limestones if hard and dense are ordinarily satisfactory, but many sandstones are friable and excessively porous and commonly are clay-bearing. Shales generally make poor aggregate material, being soft, light, weak and absorptive. Most igneous rocks are satisfactory, being normally hard, tough and dense. Tuffs and certain flow rocks may be extremely porous and have high absorption and low strength. Metamorphic rocks differ in character. Most marbles and quartzites are usually massive, tough and dense. Gneisses are ordinarily very tough and durable. Some schists contain micaceous minerals which are undesirable because they are soft, laminated and absorptive. Micaceous minerals are susceptible to weathering along cleavage planes and thereby impair strength and durability. Some schists and slates in particular are thinly laminated and tend to assume flat slabby shapes which lack strength.

Any or all of these rock types may be rendered undesirable because of harmful exterior coatings. Weathering processes, particularly the action of ground waters, deposit these coatings. The most common coatings are calcium carbonate, clay, silt, opal, chalcedony, iron oxide, manganese oxide and gypsum. Particles with these coatings are generally undesirable as aggregates. The bond between particle and coating may be weak and decrease the strength of the aggregate-cement bond.

The chemical properties which may affect service life of concrete are 1) reaction of certain rocks and minerals with high-alkali cement (alkali-aggregate reactivity), 2) leaching of water soluble substances, 3) solution of certain secondary minerals, such as the zeolites, to release sodium and potassium which aids in attacking susceptible aggregate particles, 4) oxidation by weathering to produce compounds that may retard cement hydration (Mielenz, 1946, p. 311).

Alkali-aggregate reactivity has been discussed at length in many publications (see selected references). A reactive aggregate is any rock, gravel or sand that contains one or more constituents that react chemically with the alkalies (sodium and potassium) in some types of portland cement. This reaction causes expansion, cracking and deterioration of concrete and arises from osmotic pressures produced by the formation and hydration of alkali silica gels. The gels are formed through interaction between the mineral aggregate and the alkalies which are liberated by the cement during hydration (McConnell et al, 1950, p. 234). Opal (amorphous hydrous silica) is the most conspicuous aggregate material reacting in this manner. Other rocks and minerals known to be reactive are: glassy volcanic rocks of medium to high silica content (andesite and rhyolite), chalcedonic rocks, certain phyllites which contain a hydromica, and the minerals tridymite and heulandite. Any rock containing a significant proportion of reactive substances may be deleteriously reactive; thus normally non-reactive sandstone, shale, basalt, granite and other rock types may be harmful if impregnated or coated with opal, chalcedony or other reactive substance.

Certain sulfide minerals, such as the iron sulfides, pyrite and marcasite, oxidize and cause unsightly rust stains or generate acidic compounds injurious to the concrete matrix and cause pop-outs. Chemical salts such as sulfates, chlorides, carbonates, and phosphates also occur in some aggregates. Some of these substances dissolve easily or react to impede the setting of the cement.

A chemical alteration contributing to physical unsoundness is hydration. Shales, clays and some rock nodules are examples of materials which expand when they absorb water and shrink as they dry. This absorptive character increases the rock's susceptibility to disruption by weathering.

Most of the above features can be observed in the field and on the basis of observations laboratory test procedures can be set up to further evaluate the properties of the aggregate.

Laboratory Phase of Selection and Control of Materials

Laboratory testing is a means of scientifically evaluating the suitability of aggregate material. In an attempt to forecast the behavior of the aggregate in concrete, numerous tests have been devised, many of which are complicated and require expensive equipment and trained technicians. Several of these tests have been used for many years and are familiar to those in concrete construction work. A strong effort is being made to standardize testing procedures throughout the nation and many laboratories use, with little or no modifications, test methods as set forth in detail by the American Society for Testing Materials. The principal tests performed on aggregates are for toughness and abrasion resistance, soundness, organic content, grading, specific gravity, absorption, alkali-aggregate reactivity and thermal incompatibility. Petrographic examination in greater detail than possible during field examination supplements the laboratory tests.

Petrographic Examination

Petrographic examination is a laboratory method of determining physical and chemical properties of aggregates primarily by visual appraisal. Standard techniques for mineral identification which commonly involve the use of the petrographic microscope and micro-chemical tests are employed. Representative samples containing hundreds of particles are carefully examined and classified as to 1) rock type 2) physical condition 3) chemical stability—presence of reactive or otherwise deleterious ingredients 4) shape of particles presence and 5) nature of particle coatings. Reports are presented in table form to show percentage composition, condition of the rock types present, and percentage of reactive ingredients, as well as diagnostic features of the particular constituents and the relative qualities of the different size fractions. Examination by petrographers experienced in concrete work permits interpretation of routine laboratory tests and aids in comparing new aggregates with other aggregates for which service data are available. On the basis of petrographic observations supplementary tests other than the usual laboratory tests may sometimes be recommended.

FIGURE 12. Petrographer examining material to determine suitability for aggregate. *Photo by Mary Hill.*

Routine petrographic examinations can also be used to control the quality of aggregates especially when materials containing marginal proportions of unsound ingredients are used. For example, the California State Division of Highways makes continuing petrographic examinations of aggregate to be used for highway construction from the Sisquoc River in Santa Barbara County to determine the percentage of contained reactive opaline shale.

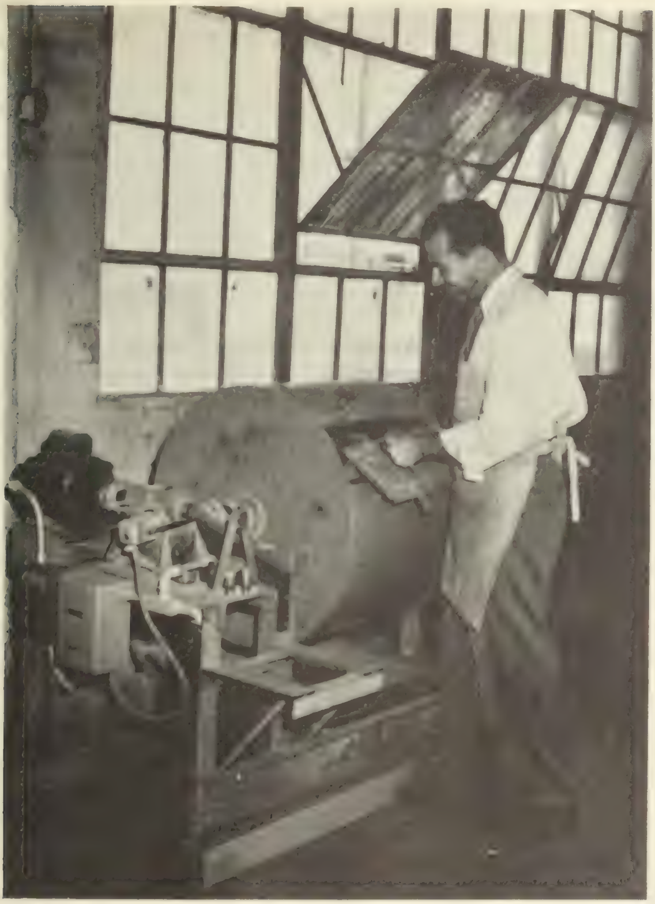

FIGURE 13. Los Angeles Abrasion Machine (L.A. Rattler). Toughness and resistance to abrasion of coarse aggregates are determined with this machine. Gravel and metallic spheres are placed in the cylinder and revolved at 30 to 33 rpm for 100, 500, or 1,000 revolutions. *Photo by Mary Hill.*

Laboratory Test Methods of Determining Aggregate Suitability

Physical Tests

Toughness and resistance to abrasion are determined by abrasion tests, such as the Los Angeles Rattler and wet shot tests.

Los Angeles Rattler Method. The Los Angeles Rattler method is used to determine the resistance of mineral aggregate to combined impact and abrasion in a rotating cylinder containing metallic spheres. The procedure consists of placing a graded and weighed sample in a metal cylinder 28 inches in diameter and 20 inches in height with 6 to 12 iron or steel spheres approximately $1\frac{7}{8}$ inches diameter, each weighing about 1 pound. The machine is rotated about a horizontal axis at a speed of 30 to 33 rpm. for 100, 500, or 1,000 revolutions, after which the sample is removed, resieved and reweighed. The difference between the original and the final weight of the test sample is expressed as a percentage of the original weight and reported as the percentage of wear.

Wet Shot Method. The wet shot test is conducted in a manner similar to the Los Angeles Rattler except that water is present in the cylinder.

Soundness of aggregates is determined by two methods: the quick sodium sulfate (or magnesium sulfate) test, or the slower freeze-thaw tests.

Sodium Sulfate or Magnesium Sulfate Soundness Test. The soundness of aggregates is determined by a quick test method which measures the resistance of aggregates to disintegration by the force of crystallization of salts absorbed from saturated solutions of sodium or magnesium sulfate. The procedure involves sieving and weighing the samples, immersing desired size gradings in prepared hot solutions of these salts for 16 to 18 hours, removing and drying and then repeating the entire cycle. After the final cycle, the samples are washed, dried, resieved and reweighed. The weighted average percent loss is then calculated from the percentage of loss for each fraction. The fraction larger than $\frac{3}{4}$ inches is examined visually to detect any disintegration, splitting, crumbling, cracking, flaking, etc., caused by crystal growth in the fractures, pores and capillaries.

Freeze-Thaw Test. The freeze-thaw method consists of mixing the aggregate sample with a standard mixture of cement, entrained air, and water to form test beams. These beams are cured and then subjected to cycles of freezing at 0° C and thawing to 40° C. The change in the dynamic modulus of elasticity is measured periodically by sonic equipment (electronically). Durability is judged by the percent change in the modulus of elasticity with continued cycles of freeze-thaw. This method has the disadvantage of being much slower than the sodium sulfate or magnesium sulfate test.

Organic Content. The organic impurity in the finer fractions of the aggregate sample is determined by a color test using a 3 percent sodium hydroxide solution. A specified amount of the sample is placed in a container with the solution, agitated and allowed to stand 24 hours. The color of the liquid is then determined by electric colorimeter compared to a standard color solution of tannic acid, alcohol, and sodium hydroxide.

Size and Grading. The determination of the particle size distribution of aggregates is a standard laboratory procedure which involves the use of sieves. The sample is weighed and run through nested sieves of progressively finer mesh openings, vibrated either mechanically or by hand. The size fraction that accumulates on each sieve is then weighed and the results are reported variously as total percentages passing each sieve, as total percentages retained on each sieve, or as an artificial number called the ''fineness modulus.'' The fineness modulus is obtained by adding the cumulative percentages retained on the #100, 50, 30, 16, 8, 4, $\frac{3}{8}$ inch, $1\frac{1}{2}$ inch, and 3 inch sieves and dividing by 100. The particle size classification scheme used by most of the aggregate industry is very different from grade size classification commonly used by geologists. The accompanying table compares the geologic classification to the industrial classification. Note that in the geologic classifi-

Comparison of geological size classification with size used in sand and gravel industry.

Size in millimeters	Geologic classification Wentworth (1922)		Industrial classification using A.S.T.M. standard sieves	A.S.T.M. sieve number	Size in millimeters
			GRAVEL	¼″	6.350 mm.
4 mm.	PEBBLE		SAND	#4	4.760 mm.
2 mm.	GRANULE			#8	2.380 mm.
1 mm.	VERY COARSE	SAND		#16	1.190 mm.
.500 mm. (½)	COARSE			#30	.590 mm.
.250 mm. (¼)	MEDIUM			#50	.297 mm.
.125 mm. (⅛)	FINE			#100	.149 mm.
.062 mm. (1/16)	VERY FINE			#200	.074 mm.
	SILT		SILT AND CLAY		
.004 mm. (1/256)	CLAY				

cation "sand" ranges from $\frac{1}{16}$ mm (or .062 mm) to 2 mm; whereas in industry "sand" ranges from .074 mm, (a slightly larger size—which is material retained on the 200 mesh sieve), to more than 6 mm (or $\frac{1}{4}$ inch).

Specific Gravity and Absorption. Specific gravity and absorption are utilized as a basis for designing concrete mixtures and are also important in determining the quality of the aggregate. The test procedure consists of weighing the water-saturated sample both in air and in water, and again after it has been oven-dried. Absorption and specific gravity are then calculated using the results of the weighings. Specific gravity is expressed by the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Absorption is expressed as a percent ratio of the weight of moisture absorbed to the dry weight of the material.

Sand Equivalent. The California Division of Highways has recently adopted a test to determine the effective volume of detrimental fine dust or clay-like materials in fine aggregates (California Standard Specifications, 1954, p. 26). The test is performed by shaking, using a

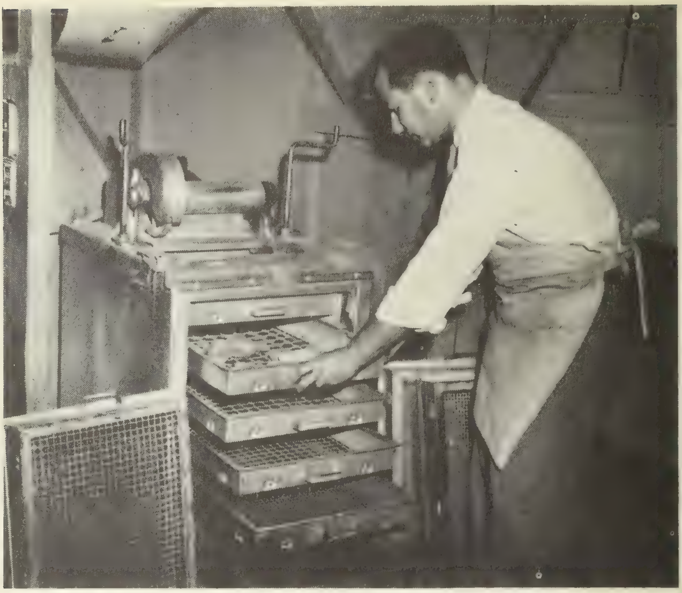

FIGURE 14. Coarse grading machine used to determine particle-size distribution of coarse aggregates. The sample is separated mechanically into a series of sizes using sieves of decreasing size. *Photo by Mary Hill.*

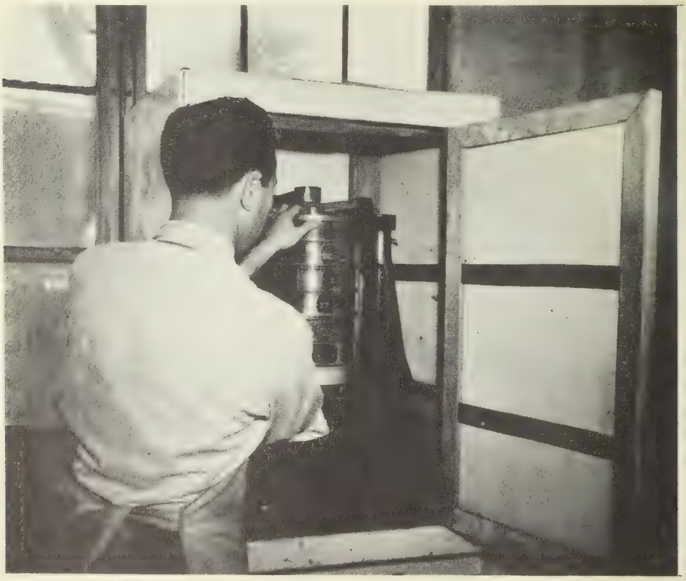

FIGURE 15. Ro-Tap sieve shaker used to determine particle-size distribution of fine aggregates. The machine mechanically shakes the sand through nested sieves of decreasing size openings. *Photo by Mary Hill.*

prescribed technique, a known volume of the sample in a glass cylinder with a water solution of calcium chloride, glycerine, and formaldehyde. The mixture is permitted to stand 20 minutes and the relative volume of the clay and sand is then measured. The sand equivalent is the ratio of the volume of sand to the volume of clay and is expressed as a whole number. The higher the number the lower the clay content and vice versa.

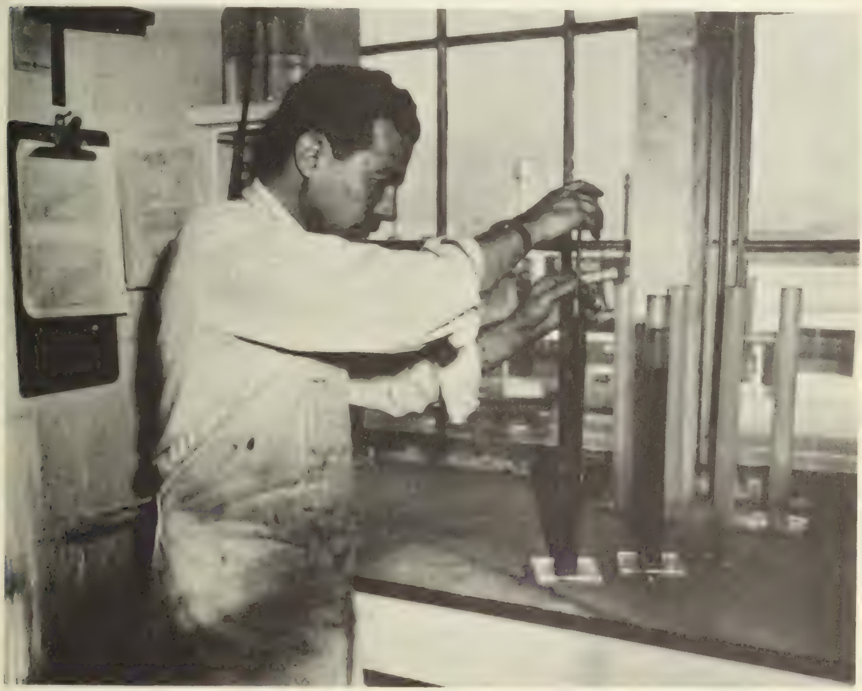

Figure 16. Sand-equivalent test performed at the Division of Highways Material Research Laboratory in San Francisco. This test provides a rapid determination of the relative proportion of sand to detrimental clay-like material in fine aggregate. *Photo by Mary Hill.*

Reactivity Tests

Petrographic Examination. There are several approaches to the determination of harmful quantities of chemically reactive impurities in aggregates. Petrographic examination for physical and chemical properties has been mentioned previously. During such examinations the petrographer is alert for the presence of constitutents that may be chemically unsound. By using the petrographic microscope one can readily identify reactive ingredients such as opaline silica, chalcedony, and volcanic glass and estimate the quantity present. On the basis of petrographic observations aggregates containing suspected reactive materials can then be subjected to such substantiating laboratory tests as the mortar bar expansion test and the chemical method of determining potential reactivity.

Mortar Bar Expansion Test. One method of testing reactive aggregate is the mortar bar expansion test in which the test aggregate is sieved and mixed with cements of known alkali content to form 1 inch x 1 inch x 10 inch mortar bars. These are cured under laboratory conditions of controlled temperature and heat for specified lengths of time, usually 1 to 2 years. Periodically the length of the bars are measured and the reactivity expressed as the percentage of expansion in a given length of time. The excessive length of time required to perform this test has led to the establishment of a quick chemical test.

Chemical Test for Potential Reactivity of Aggregates. The chemical test for determining potential reactivity of aggregates is based on the degree of reaction of the aggregate with a sodium hydroxide solution under controlled laboratory test conditions. The procedure as described by Mielenz et al., 1950, involves digesting a pulverized sample of the material in a sodium hydroxide solution and filtering the mixture. A portion of the filtrate is analyzed to determine the amount of dissolved silica. The alkalinity of the balance of the filtrate is determined chemically by comparison with a solution of known acidity. The amount of dissolved silica and the reduction in alkalinity is used as a measure of the potential reactivity.

Thermal Tests

It has been suggested that a cause of distress in finished concrete is due to the internal stresses that arise during changes in temperature. Different rates of thermal expansion of the aggregate materials and the mortar is the suggested cause. This hypothesis is the subject of tests still underway by the National Sand and Gravel Association laboratory workers (Walker et al., 1952, p. 661) who indicate that further work will be needed before the significance of the effects of thermal characteristics can be evaluated.

GENERAL SPECIFICATIONS

The study of the results of laboratory tests of aggregates that have good service records in concrete has led to the establishment of certain minimum requirements or specifications to which aggregates are expected to conform. These specifications are designed so that completely serviceable concrete would be made, using any aggregate that meets the requirements. Most specifications are written by the government agencies, engineering societies and concrete technologists with an attempt to conform to one standard set of specifications, those set up by the American Society for Testing Materials. Modifications of these standards for certain types of concrete work make it difficult to compare individual requirements of these organizations. Therefore to evaluate the suitability of a deposit by judging the test results of selected samples is a difficult task. Some deposits which may not meet certain required specifications may have to be utilized because of other outside factors, such as the greater expense of hauling a more suitable aggregate.

In general, aggregate from an untried deposit will be satisfactory for most uses if it meets the following minimum standards (these specifications are a general average of the basic requirements recommended by the ASTM, California Division of Highways, U. S. Army Corps of Engineers, and the U. S. Bureau of Reclamation).

Abrasion—The abrasion loss should be less than 30 percent.

Soundness—The loss in the sodium sulfate test should be less than 10 percent.

Specific Gravity—The specific gravity should be greater than 2.55.

Size and Grading—
a. The deposit has proper grading so that the fine aggregate should contain no more than 45 percent of the material between two consecutive sieve sizes.
b. The fineness modulus should be between 2.3—3.1.
c. No more than 5 percent of the material should pass the #200 sieve.

Reactivity—A mortar bar containing the aggregate should have an expansion less than 0.10 percent in one year with a 0.8 percent alkali content cement.

Absorption—The absorption should not exceed 3 percent.

Durability—The concrete containing the aggregate should not have a loss in the modulus of elasticity exceeding 50 percent in the freeze-thaw test.

Sand Equivalent—The fine aggregate should have a sand equivalent of not less than 75.

METHODS OF IMPROVING QUALITY OF AGGREGATE

Many natural deposits contain material that does not meet minimum specifications and many methods of improving the grade of deposits are employed. Deposits ordinarily need beneficiation for a variety of reasons: (1) excessive amounts of physically unsound or foreign matter are present; (2) the particles have harmful coatings; (3) thick clay lenses are interbedded in the deposit; (4) the materials are not present in the necessary size gradations; (5) alkali-aggregate reactive ingredients are present.

Many methods are used in an attempt to remove undesirable ingredients. Simple washing generally removes silt, clay coatings, some fine free mica, easily soluble salts and light organic matter. Log washers in particular have been used successfully to remove sticky clay from deposits containing sand and gravel embedded in clay.

Soft particles, such as those composed of shales and friable sandstones, have been removed by the use of various types of impact crushers. This method has had varying degrees of success as soft easily crushed material cannot be removed without losing some of the harder good material.

Removal of objectionable particles, such as soft and porous rock, and foreign matter, such as coal, wood, and clay, has been successfully accomplished on the basis of specific gravity by use of heavy media separation (Lenhart, 1953). Mechanical means of scrubbing or pulverizing these particles in rotating cages with or without ball charges has been tried for years with high maintenance costs and only partial success. Heavy media separation, a process used by the mining industry, is a relatively new method of removing these harmful ingredients. This process, also known as ''sink-float,'' was applied after laboratory studies of certain deposits where this process is now employed indicated that the harmful ingredients had a much lower range of specific gravities than did the desirable particles. Tests conducted on the sink fraction showed that a much improved quality of aggregate material could be obtained (Walker and Bloem, 1953). Briefly, the process consists of placing the material to be treated into an artificial heavy liquid, made up of finely ground magnetite (Fe_3O_4), or ferrosilicon, or a mixture of both suspended in water. A liquid that has a specfic gravity range of from plus 1.0 to 3.4 can be obtained to correspond with the specific gravity of the materials to be removed. Usually a specific gravity of 2.50 to 2.55 is used since the harmful ingredients range below 2.50. The desired materials sink and the undesirable lighter ingredients are floated off. The magnetite and ferrosilicon, being magnetic, are easily recovered. This process is best used where a marked difference in specific gravity exists between the harmful ingredients and the rest of the aggregate (Price, 1953). It will not, for example, remove reactive particles whose specific gravity is the same as the suitable rocks of the bulk sample.

Another method for removing deleterious objects and based on specific gravity differences is the use of simple jigging machines. Such machines have been used successfully in the midwest to remove particles such as coal and ochre whose specific gravities were 2.25 or less (Sheets, 1955).

Separation by size has been employed to remove harmful ingredients where the unwanted portions were concentrated in certain sizes. When they occur in the larger sizes it is a simple matter of scalping and wasting to reduce the amount of contaminants; excessive fine-sized material, such as clay, is largely removed while suspended in washing water.

Hand picking also has been used effectively to remove deleterious ingredients. In this simple but comparatively expensive operation a man is stationed by a moving belt to remove manually the obvious contaminants such as rotten gravels or clay lumps.

In pits where objectionable material is interbedded with the desired material, selective excavation is used to avoid expensive beneficiation processes. For example, stratified deposits with interbedded thick lenses of clay have been worked satisfactorily by stripping and wasting the clay layers and mining the gravelly strata separately.

Unsatisfactory size gradation of materials can be met by wasting portions or by supplying deficiencies. The gradation of sand and gravel in a natural deposit often does not conform to specifications and processing takes several forms. Poor grading in the sand sizes may be met by adding blended sand, crushing the larger size material, or wasting portions of the sizes present in excess. Rod mills are used widely to produce sand from the fine gravels. Deficiencies in the coarse aggregate size are remedied by crushing oversize cobbles and boulders to size.

Where ingredients which may be chemically reactive cannot be removed by the aforementioned methods, other techniques have been devised whereby deposits that contain reactive aggregate could be used without beneficiation. Alkali-aggregate reaction has been reduced successfully in many instances by the use of low-alkali cement, containing less than 0.6 percent alkalies, with reactive aggregate. Another preventive method involves the addition of pozzolanic materials. Pozzolans are defined as ''natural or artificial siliceous and aluminous substances which are not cementitious themselves but which react with lime in the presence of water at atmospheric temperatures to produce cementitious compounds'' (Mielenz, et al., 1951, p. 311). Pozzolans are used in the concrete mix as a partial replacement of the portland cement. Reaction is partly reduced by thus decreasing the amount of cement and its contained alkalies. The pozzolanic material also reacts chemically with alkalies released as the cement hydrates and absorbs them. Materials that are reactive themselves when present as aggregate constitute the best pozzolans when they are fine-ground, calcined and used as described above. The common pozzolans are made from volcanic ash, pumice, obsidian, tuff, diatomite, opaline shales, and clays (Drury, 1954).

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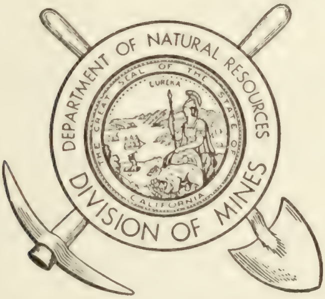

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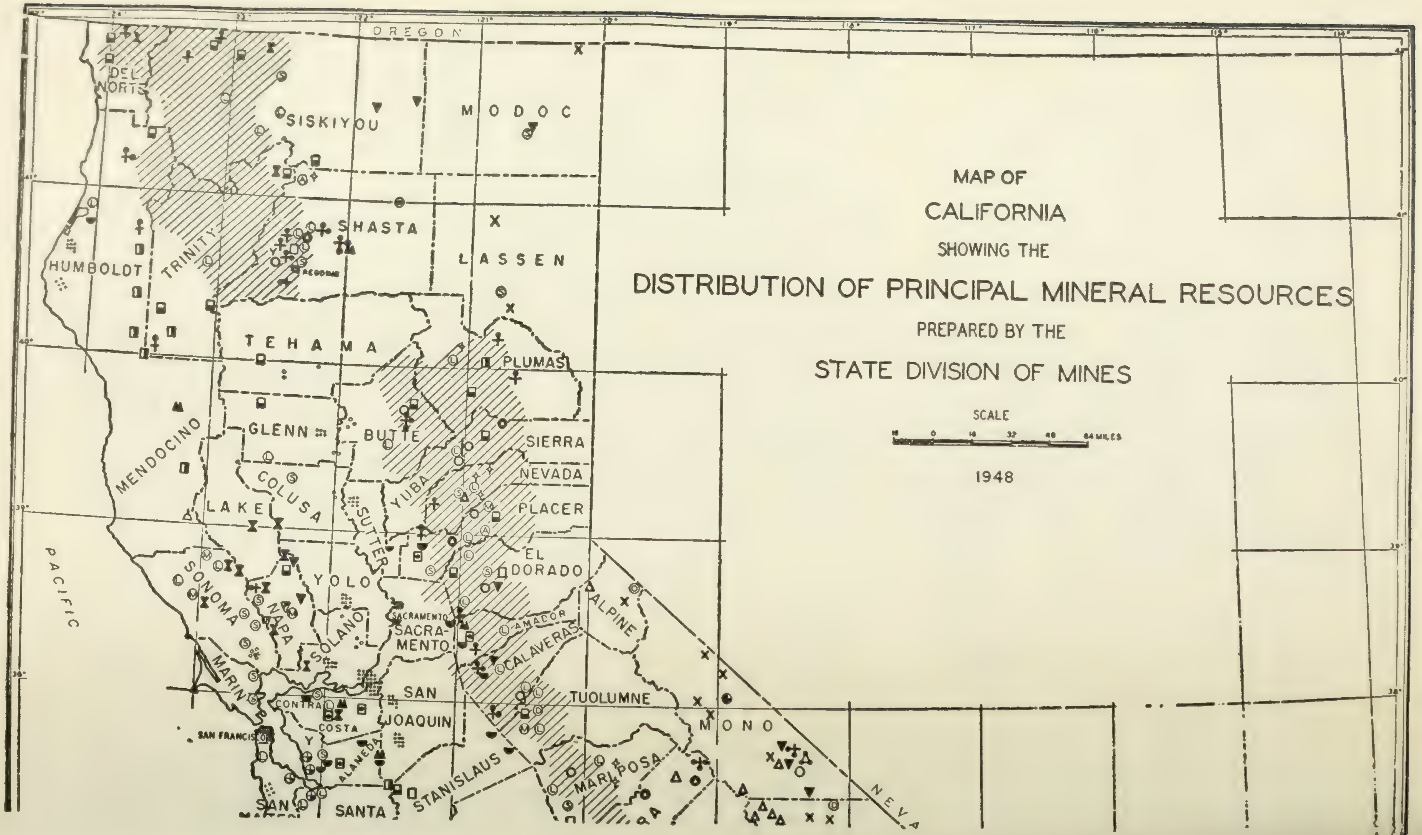
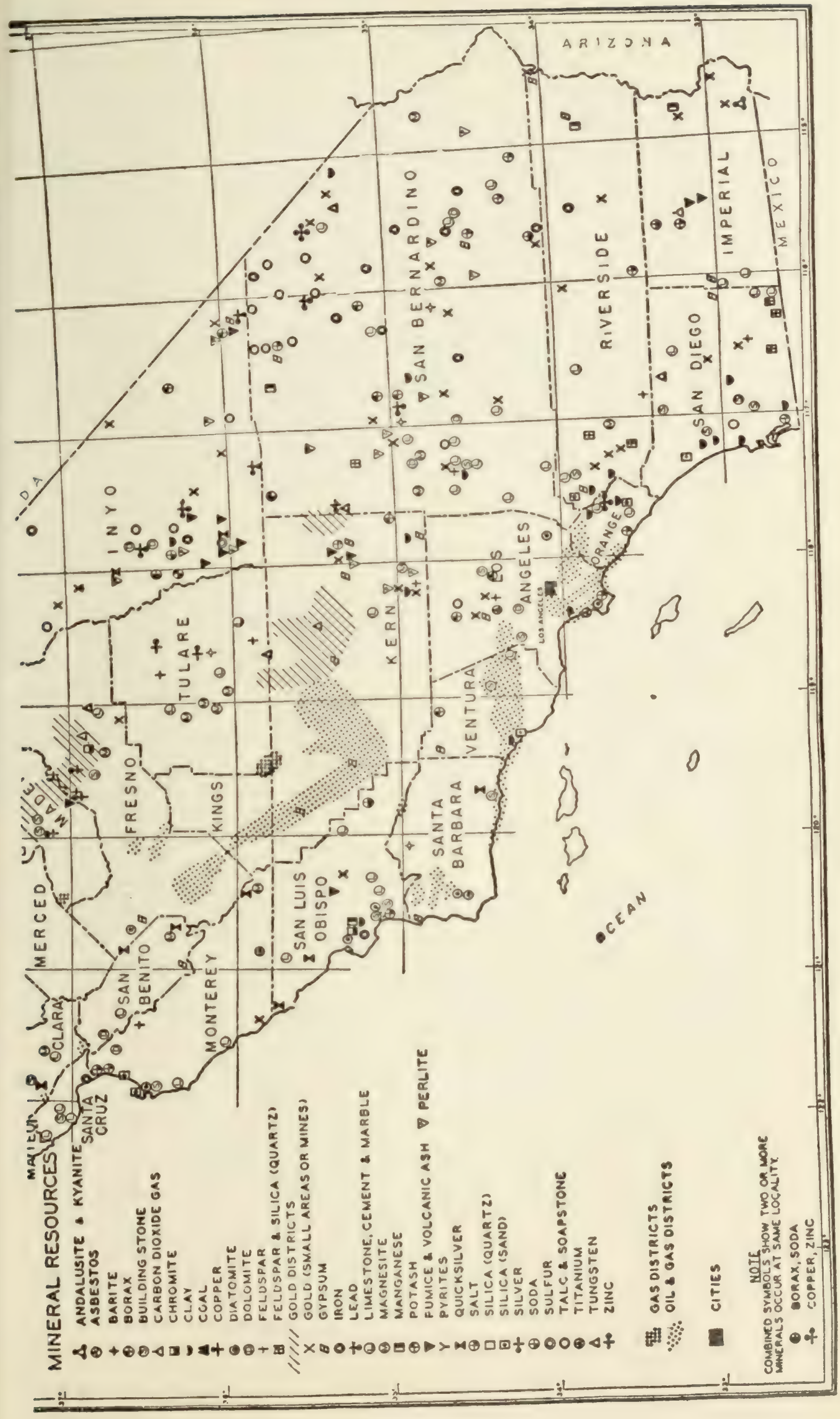


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES

SCALE

1948

0
16
32
48
64 MILES
OREGON
NEVA
PACIFIC
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
MENDOCINO
COLUSA
YUBA
PLACER
LAKE
SUTTER
EL DORADO
SONOMA
YOLO
NAPA
SOLANO
SACRAMENTO
SACRA-MENTO
AMADOR
ALPINE
CALAVERAS
MARIN
SAN JOAQUIN
TUOLUMNE
CONTRA COSTA
SAN FRANCISCO
MONO
ALAMEDA
STANISLAUS
MARIPOSA
SAN
SANTA
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY.
BORAX, SODA
COPPER, ZINC
MATEO
SANTA CRUZ
CLARA
SAN BENITO
MONTEREY
MERCED
MADERA
FRESNO
KINGS
TULARE
INYO
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
KERN
LOS ANGELES
LOS ANGELES
ORANGE
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN

BASIC STUDIES IN THE CLAY INDUSTRY

A SERIES OF PAPERS PRESENTED AT THE CLAY INDUSTRIES CONFERENCE AT THE UNIVERSITY OF CALIFORNIA IN 1952

GEORGE B. CLEVELAND, EDITOR
GEOLOGIST, CALIFORNIA DIVISION OF MINES

CONTENTS

Page
Clays and clay mineralogy, by Joseph A. Pask ---------- 113
Properties of clays, by W. J. Knapp ---------- 125
Mineral exploration and winning of clays, by E. H. Wisser and Mort D. Turner ---------- 131
Clay testing, by W. O. Brandt ---------- 145
Testing of clays, by L. H. Lohman ---------- 151
Soluble salt deposits on clay wares, by Joseph A. Pask ---------- 155
Clay preparation and stiff-mud forming methods, by Clark Sutherland ---------- 167
The drying of clay products, by R. K. Hursh ---------- 177
The firing process, by R. K. Hursh ---------- 193
Temperature measurement in kilns, by James L. Hall ---------- 207
Pyrometry, by Ralph I. Brogie ---------- 219

PLATES

Plate 1. Map showing clay deposits of California ---------- In pocket

INTRODUCTION

Basic studies in the clay industry is a series of papers presented at the Clay Industries Conference early in 1952. This conference was sponsored by the College of Engineering and the Extension Division of the University of California.

The purpose of the conference was to present the practical aspects of fundamental principles related to the ceramic arts. In view of this practical approach the conference attracted not only representatives of research laboratories, but also a large number of persons seeking information that could be directly applied to their own plant problems. These papers should, therefore, make up a source book for both the plant and the laboratory, and should serve as an aid in solving everyday problems faced by the ceramic industry.

Conferences of this type are of great value in the development and growth of the ceramic industry in California—an industry based on utilization of non-metallic resources of the state. It is hoped that sufficient interest will be generated to warrant holding other conferences in the future.

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Berkeley 4, California

CLAYS AND CLAY MINERALOGY

By Joseph A. Pask *

INTRODUCTION

Early definitions of clay included any unconsolidated or weakly consolidated rock that contained an appreciable amount of particles less than 2 microns, 0.002 mm. or 0.00008 inch, in diameter, indicating the presence of a definite colloid fraction. The term silt was applied to materials with particles less than 50 microns or 0.050 mm. in diameter; very fine sand was defined as particles less than 0.10 mm. in diameter. Such definitions, proposed by early geologists, soil scientists, and workers in soil mechanics, thus included a variety of materials that differed appreciably in chemical and mineralogical composition and in physical properties.

With the development and application of various experimental identification techniques it was found that the clay fraction was composed of definite crystalline compounds—in most cases essentially hydrous aluminum silicates. In present-day classifications, clays are primarily distinguished by their mineralogical composition. The particle-size definition still applies to all the clays, but it is not sufficiently extensive and delineatory.

The ceramic engineer or ceramist is particularly interested in the properties of the clay-water systems that are essential for forming clay wares, such as plasticity or workability, and shrinkage and strength of the ware after drying. These properties are dependent upon the colloidal nature of the clay minerals and a correspondingly large surface area with an electrical charge which is expressed as base or cation exchange. The ceramic engineer is also interested in the pyrochemical reactions that occur upon heating clays which determine the firing temperatures and the properties of the fired articles.

As a consequence, from the ceramist's viewpoint, the definition for clay is more specific and is based on the following characteristic points: *(a)*, it contains secondary minerals, and *(b)*, these minerals are essentially hydrous aluminum silicates; *(c)*, it contains a colloidal fraction; *(d)*, when it is mixed with water it has the property of plasticity; *(e)*, clay becomes hard and durable when fired.

The properties vary with differences in composition. The clays are expected to show considerable differences because they are secondary, having been formed by the weathering of primarily igneous rocks that may have considerable variation themselves. The clays may stay in place as residual deposits or may be transported, usually by water, to form sedimentary or secondary clays. Thus, the very nature of the clay deposit formation invokes a considerable degree of variation in mineralogical composition. It is important to know the nature of these variations and their significance.

CLAY MINERALOGY

A critical examination of the structure of the clay minerals should provide an appreciation of and reasons for the great variation in clay mineral composition. The clay minerals are essentially classified into three main groups: kaolinites, illites, and montmorillonoids. Attapul-

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* Professor of Ceramic Engineering, University of California, Berkeley, California.

Table 1. Ionic sizes of certain elements, radii.

Ion	A^0	Ion	A^0
O^{--}	1.32	Ca^{++}	1.06
$(OH)^-$	1.32	Fe^{+++}	0.67
Si^{++++}	0.39	Fe^{++}	0.83
Al^{+++}	0.57	Na^+	0.98
Mg^{++}	0.78	K^+	1.33

gite, a fibrous clay mineral, and others are recognized but found only in minor amounts. Also, because of similarity in structures there is a tendency among some workers to include even chlorites and serpentines under a broad classification of clay. The clays that the ceramist deals with, however, practically always contain clay minerals from the three main groups above.

Development of Layer Structures

All matter is composed of combinations of ions and atoms. The clay minerals can be considered to be primarily ionic; theoretical structure combinations are based largely on geometric and electrovalence considerations. The principal ions in the clay minerals are Al^{+++}, Si^{++++}, O^{--}, and $(OH)^-$. These have characteristic effective sizes and for convenience can be visualized as spheres of certain diameters that can be packed in various ways according to geometric principles. The total positive charges must equal the total negative charges to maintain electrical neutrality.

The sizes of Si^{++++} and O^{--} are such that, upon packing, four oxygens form a tetrahedron with a cavity in the center of the proper size to hold the Si^{++++}. This arrangement is referred to as the $(SiO_4)^{----}$ group. The chemical bonds in this group are strong, causing them to resist dissociation. Thus, the $(SiO_4)^{----}$ group is characteristic in all silicates, and it can be thought of as a chemical radical. Each of four bonds from the silicon to an oxygen is equivalent to a charge of plus one. Consequently, each oxygen has one unsatisfied negative valence, accounting for the negative 4 charge on the group.

The Al^{+++} is larger than Si^{++++}. A geometrical close packing of six oxygens as an octahedron is required to form a cavity of the proper size for Al^{+++}. This forms the $(AlO_6)^{====-}$ or $(Al(OH)_6)^{---}$ grouping. The valence charge of plus 3 of Al ion is distributed among the six oxygen or hydroxyl neighbors in the (AlO_6) or $(Al(OH)_6)$ group, making each bond equivalent to an average charge of plus $\frac{1}{2}$. The $(OH)^-$ ions cannot be distinguished from O^{--} ions on the basis of determination of crystalline structure by x-ray diffraction, and are thus presumed to be similar in size. The choice of anion is dependent upon the valence charge requirements for the structure, being either one or the other or a mixture of both.

These groups are assembled into layers extensive in two directions. The (SiO_4) groups form silica layers with a hexagonal network symmetry in the extensive plane. Three oxygen ions of every group are shared between two Si^{++++} ions, thus satisfying their valence. The fourth O^{--} ion would have to be replaced by an $(OH)^-$ ion if electrical neutrality were desired. This does not happen because of energy requirements, and thus the additional negative charge has to be balanced by another cation.

Similarly, the (AlO_6) or $(Al(OH)_6)$ groups, or some intermediate groups, are linked to form a layer extensive in two directions. In this layer an oxygen position cannot be adjoined by more than two Al ions. Because the Al distributes its charge as $\frac{1}{2}$ per bond, the oxygen ion then has an excess charge of one minus. Thus, in order to maintain electrical neutrality the O^{--} must be replaced by $(OH)^-$ ions and the aluminum groupings become $(Al(OH)_6)$. Taking into account sharing of $(OH)^-$ ions between groupings, the average composition of the layer becomes $Al(OH)_3$, which is the formula and structure for the mineral gibbsite, and it is thus called the gibbsite layer. This layer has an open structure with only two-thirds of the possible Al positions filled. Filling of the other positions does not occur, because there then would be an excess of positive valences.

Under certain conditions, however, Al^{+++} can be replaced by Mg^{++}. Because of the valence difference, three Mg^{++} are necessary for every two Al^{+++} in order to provide an equal total positive charge. Complete substitution results in a layer composed of $(Mg(OH)_6)$ groups which by sharing form brucite whose composition is $Mg(OH)_2$. Theoretically, a continual transitional change is possible between gibbsite and brucite layers although apparently only a partial substitution of Al^{+++} by Mg^{++} actually occurs. Substitutions of Fe^{++} or Fe^{+++} can also occur for Al^{+++}.

The only substitutions in the silica layer that have been reported are Al^{+++} for Si^{++++}. The corresponding lack of electrovalence balance may be taken care of by introduction of K^+ ions between the layers where they sit in the hexagonal cavities of the silica layer close to the source of charge.

These layers are further assembled in various combinations to form different kinds of compound layers which characterize the different clay minerals.

Development of Compound Layer Structures and Clay Minerals

Kaolinite Group. The kaolinite minerals are assemblages of compound layers, composed of one silica and one gibbsite layer, held together weakly by van der Waals forces. The layers within the compound layers themselves, however, form inseparable integral units by mutually sharing O^{--} ions which replace the $(OH)^-$ ions present in each layer when the layer is considered as an individual electrovalence balanced unit. Each of these bridge O^{--} ions is balanced by two plus $\frac{1}{2}$ charges from two Al^{+++} neighbors and plus one charge from the Si^{++++} neighbor. The crystal habit is therefore platy because of the extensive layer structure of the group and the weak bonding between the compound layers.

Kaolinite, the most common mineral of this group, nacrite, and dickite all have this type of layer structure. The oxide formula thus is $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, and the structure formula—$(OH)_4Al_2(Si_2O_5)$. The differentiating characteristic between these minerals is the manner of packing or orientation of the compound kaolinite-type layers relative to each other.

Halloysite is formed by the interleaving of layers of oriented water molecules between the kaolinite layers, the formula being

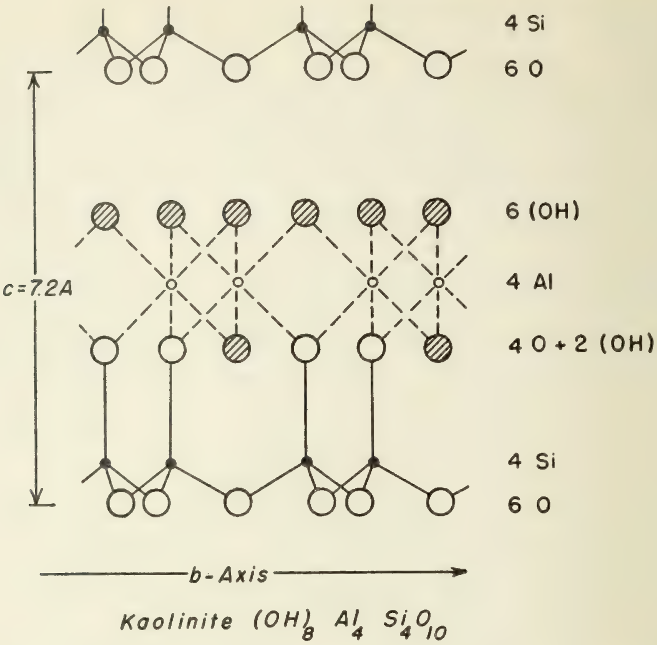

FIGURE 1. Diagrammatic representation of the crystal structure of kaolinite. (After Gruner.)

$(OH)_4Al_2(Si_2O_5) \cdot nH_2O$ with n ranging from 0 to 2. Anauxite is formed by the interleaving of silica layers between the kaolinite layers, the formula being $(OH)_4Al_2(Si_2O_5) \cdot nSiO_2$ with n ranging from 0 to 1.

Evidence indicates that solid solution substitutions do not occur in the kaolinite layers, except perhaps in minor amounts. Thus, the presence of impurities as may be indicated by chemical analysis, or variations in physical and thermal properties can be considered to be due to admixtures of other minerals. These impurity minerals may be fine enough to be in the particle size range of clays and silt.

Montmorillonoids. The montmorillonoids are minerals formed of compound layers, composed of a gibbsite layer sandwiched between two silica layers, held together weakly by van der Waals forces. The compound layers are inseparably held together by mutually shared O^{--} ions. The chemically combined water content is less than that in kaolinite, because each gibbsite layer is bonded to two silica layers instead of one and thus more of its $(OH)^-$ ions are replaced by O^{--} ions for interlayer bonding purposes.

There are undoubtedly mineralogical variations brought about by modifications in geometrical stacking, but these have not yet been worked out. Considerable variation occurs as a result of considerable substitution of Mg^{++}, Fe^{++}, and Fe^{+++} for Al^{+++} in the gibbsite layer. Complete substitution by Mg^{++} results in the specific mineral talc and if a small amount of Al^{+++} remains, the mineral is saponite. Almost complete substitution by Fe^{+++} results in nontronite. When no substitutions exist, the mineral is pyrophyllite. Actually, in most mont-

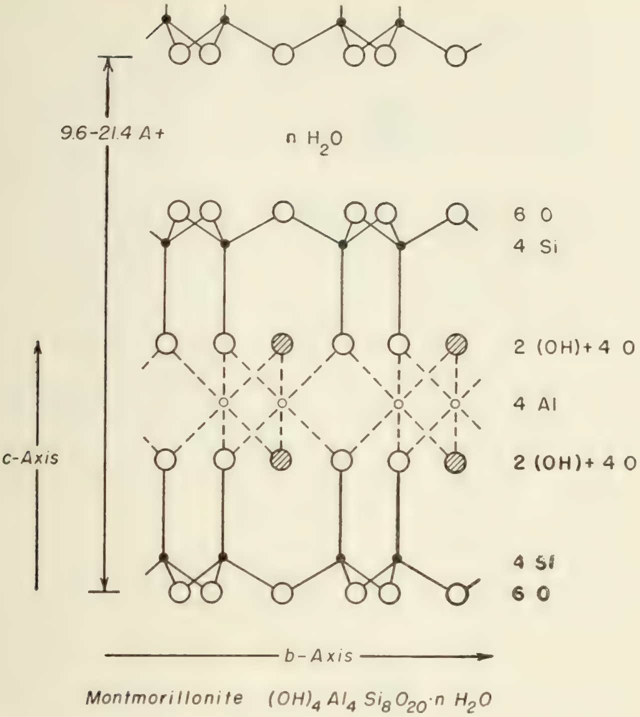

FIGURE 2. Diagrammatic representation of the crystal structure of montmorillonite. (After Hoffman, Endell, and Wilm.)

morillonoids these substitutions for Al^{+++} occur only partially. In order to maintain an electrovalence balance three Mg^{++} and Fe^{++} ions are necessary for every two Al^{+++} ions. This is physically possible because of the vacant positions in the gibbsite layer as pointed out earlier. Some workers claim that such substitutions do not occur stoichiometrically and thus a negative charge results in the crystal lattice which is responsible for the high cation exchange capacity and for the highly colloidal properties of this clay mineral group. As a result of this charge, water can be easily brought in between the layers by the exchange cations causing swelling which is common for many montmorillonites. The oxide formula is $(Al_2O_3 \cdot Fe_2O_3 \cdot MgO) \cdot 4SiO_2 \cdot H_2O \cdot nH_2O$, and the structure formula—$(OH)\ (Al, Fe, Mg)\ (Si_2O_5) \cdot nH_2O$.

Stresses are apparently set up in the crystal lattice by the ionic substitutions which prevent large crystal growth. As a consequence the montmorillonite particles are much smaller than the kaolinite particles. This fine size with a resultant large surface factor or area, together with inherent surface charges, is responsible for the unique properties associated with bentonites which are composed predominantly of montmorillonites.

Illites. The illite minerals, referred to in earlier papers as sericite or micaceous-like, basically are the same as the montmorillonoids in structure. The additional differentiating factor is substitution of Al^{+++} for about 15 percent of the Si^{++++} ions in the silica layers. The electrova-

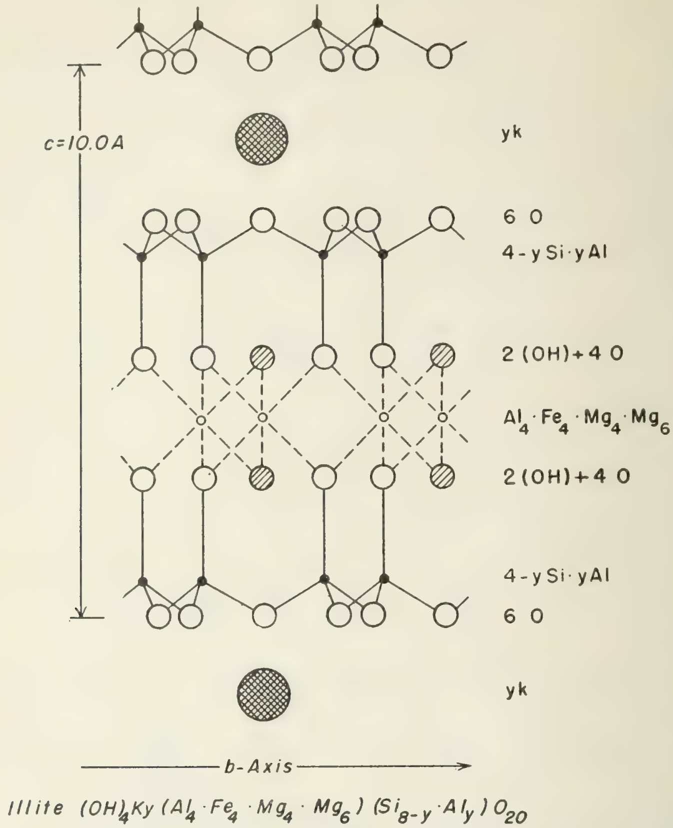

FIGURE 3. Diagrammatic representation of the crystal structure of illite. (After Grim, 1942.)

lence balance cannot be achieved by substituting four Al^{+++} for three Si^{++++} ions. The extra valence is obtained by inclusion of a K^{+} ion between the compound layers.

The presence of the K^{+} ion forms a stronger bond between the layers than that in the montmorillonoids. Thus, a larger particle size exists and less surface is available for adsorption of ions in a water suspension. Consequently, the illite minerals are not as clay-like in their properties.

The illites are also closely related to the micas which have a similar structure but with a replacement of 25 percent of the Si^{++++} atoms by Al^{+++}. The structure formula for illites is $(OH)_4Ky(Al,Fe,Mg)_4(Si_{8-y}Al_yO_{20})$ with y about one. The formula represents mica when y is two.

Other Clay Minerals. Attapulgite is a montmorillonite-type of mineral whose silica sheet structure is rearranged to form a fibrous instead of a platy particle shape.

Beidellite is often included under the montmorillonoids, but it is considered by some to be an interlayer mixture between montmorillonoids and kaolinites. In the former case, the structure is similar to the montmorillonoids and partially to the illites in the sense that substitutions of Al^{+++} for Si^{++++} are said to occur. The needed additional positive charges to attain a valence balance, however, are obtained by inclusion of additional Mg^{++} and Fe^{++} in the unoccupied positions in the gibbsite layer, instead of K^+ between the compound layers. In the latter case, because attraction between layers is weak and not due to valence bonds, it is conceivable that layers of kaolinite and montmorillonite can occur alternately in some irregular sequence producing a resulting composition equivalent to beidellite.

Serpentines and chlorites are occasionally considered as clay minerals on the basis of structure alone, although they may have clay-like properties if the particles are in the colloidal size range. These are also layer lattice minerals but with combinations of brucite ($Mg(OH)_2$) instead of gibbsite ($Al(OH)_3$) layers.

Effect on Ceramic Properties

The remarks at this point will be brief. The chief purpose will be to show that a knowledge of the atomic structure can be an aid in predicting properties and understanding the reasons for occurrences of variations.

The properties of the clay-water system will vary appreciably because of variations in the surface factor or area and surface charge for the different clay minerals. For instance, the montmorillonoids being the finest and having the largest charge require the most water to attain a certain degree of plasticity. The kaolinites being the coarsest of the clay minerals and having the smallest charge require the least water and are the least plastic.

The pyrochemical or fired properties of these minerals also vary considerably. The clay minerals of the kaolinite group would be expected to fire the whitest in color and to be the most refractory—refractoriness being determined by a consideration of the temperature at which liquid first occurs and the amount and viscosity of the liquid. This is based on the fact that fired kaolinites are represented on a two-component, Al_2O_3-SiO_2, phase diagram because of the lack of solid substitutions in the kaolinite layers. The actual refractoriness would be determined by the composition point on this diagram, being greater for compositions with higher Al_2O_3 content.

The other clay minerals are less refractory and usually fire to some shade of buff, brown, or red. The additional silica reduces the refractoriness because such compositions have a greater amount of liquid occurring at the eutectic temperature. Solid substitutions of MgO, FeO, and perhaps other oxides, result in more complex multi-component systems with new lower eutectic temperatures causing a greater decrease in refractoriness. The off-white colors are generally due to the presence of iron oxide in solid solution.

CLAYS OR CLAY ROCKS

Rocks are geological structural members, but they are not necessarily consolidated. They consist of one or more minerals. Clays are rocks that contain an appreciable amount of clay minerals. The associated nonclay minerals are determined by the nature of the rock from which the clays were formed, whether the resultant clay minerals were transported and the nature of their transportation, addition of minerals and salts from other sources, and many other factors.

Associated Minerals. The materials that occur most commonly as impurities in clays are silica, mica, feldspars, iron oxides and hydroxides, iron sulfides, aluminum hydroxides, ilmenite, anatase, rutile, soluble salts, carbonates, chlorites, serpentines, carbon, etc. In fact, because clays are secondary, it is possible to find most any mineral present with the clay minerals. Just as various solid substitutions in the crystal structure affect the properties of the clay minerals, similarly, associated or impurity minerals will affect the properties of the clays. There is one major difference however: the chemical composition of the clay minerals cannot be modified without destroying them, whereas the clay minerals in clays can be concentrated by use of proper beneficiation methods. In cases of market preparation of high grade pure kaolins beneficiation methods are generally practiced.

Refractoriness. Refractoriness of a clay is dependent upon the pyrochemical or high temperature reactions of the clay minerals and interreactions of clay and associated minerals. This property is of importance in ceramics because it determines the suitability of a clay for the manufacture of refractories and because it controls the firing behavior of a clay.

In firing a clay body certain amounts of liquid are formed. The chemical and mineralogical composition determines the temperature at which liquid appears, the amount of liquid at this and with increasing temperatures, and its viscosity. These factors affect the physical properties in the finished article and thus, in turn, control the establishment of the firing temperature and range.

Presence of associated or impurity minerals will generally lower refractoriness and also produce a fired off-white color if they contain iron oxide. About the only commonly occurring non-clay minerals in clays that increase the refractoriness are the high-alumina ones, such as gibbsite ($Al_2O_3 \cdot 3H_2O$) and diasporite ($Al_2O_3 \cdot H_2O$).

The pure kaolinitic clays are the most refractory of the clay minerals. The common impurities of quartz, feldspar, and mica will reduce the refractoriness. The resulting liquid, however, is generally sufficiently viscous to produce a long firing range. The illitic clays or mixtures of kaolinite with illite or montmorillonite have significant amounts of oxides other than alumina and silica which act as fluxes. These lower the firing temperatures. Some oxides, such as MgO and CaO, increase the fluidity of the liquid. Thus, clays containing them tend to have short firing ranges and can be easily overfired making it more difficult to meet narrow imposed specifications as to size and water absorption.

Iron oxide is a common constituent of the associated minerals and occurs either in the ferrous or ferric form, FeO or Fe_2O_3. The former is a strong flux reacting easily to form fusible liquids. The latter behaves as a refractory oxide because it requires higher temperatures for a similar reaction to occur. The FeO form normally occurs in the associated minerals. The Fe_2O_3 form is generally present as the oxide itself or as part of a mineral that readily decomposes to form Fe_2O_3. Thus, many clays may fire to a definite tan or buff color but still have a high fusion point because the iron is present as Fe_2O_3.

Color of Fired Ware. The usual colors obtained in firing clays ranging from tan or buff to brick red are due to the iron oxide. There is, however, no direct relationship between the iron oxide content and the intensity or shade of color. Many factors, such as the nature of the compound containing iron oxide, its particle size and distribution, and nature of associated minerals, affect the color. Certain oxides, such as CaO, and to a minor extent MgO and free Al_2O_3, seem to act as bleaching agents reducing the intensity of the color.

The kaolinite-bearing clays are the only ones that are expected to possibly fire white. The montmorillonoids and illites will generally fire to some buff or red color because iron is almost a universal substitution for aluminum in these minerals. However, there have been some deposits of a montmorillonoid-type reported that do fire white because of lack of iron substitutions.

Titanium oxide, either as rutile or anatase (TiO_2) or in ilmenite ($FeO \cdot TiO_2$), frequently occurs in small percentages causing the development of a yellowish-buff shade. Its presence also seems to affect the shade produced by iron oxide.

CLASSIFICATION OF CLAYS

A number of classifications of clays have been proposed both on a geologic and on a ceramic basis. However, regardless of the classification employed there are no sharp division lines between the types. Gradual changes occur from one type of clay to another, making it difficult sometimes to specifically classify a given clay. The secondary nature of clays also results in a situation whereby no two clays, although they may be very similar, are exactly alike.

Geologic classifications are generally based on the nature of formation of the clay beds. Ceramic classifications are generally based on the two properties of fired color and refractoriness. The accompanying table is a slight modification of one proposed by C. W. Parmelee.

A critical examination of the table will reveal progressive changes between types of clays, primarily in terms of mineralogical composition and a corresponding change in properties.

Classification of clays according to fired color and refractoriness.

A. White or light-firing clays
  1. Refractory (P.C.E. $\geqq 28$)
     Residual kaolins
     Sedimentary kaolins
     Ball clays
  2. Semi- and non-refractory kaolin or ball clay type contaminated, usually with feldspar.

B. Buff-firing clays
  1. Refractory (P.C.E. $\geqq 28$)
     Diasporitic clays, $> 65\%$ Al_2O_3
     Bauxitic clays, 55-65% Al_2O_3
     Flint clays
     Semi-flint clays
     Fire clays
     Plastic bond clays
  2. Semi-refractory (P.C.E. 10 to 27)
     Plastic fire clays
  3. Non-refractory (P.C.E. < 19)
     Calcareous clays and shales

C. Red, brown or dark-firing clays
  1. Refractory and semi-refractory kaolin type contaminated with iron oxide-containing mineral.
  2. Non-refractory (P.C.E. < 19)
     Ordinary brick clays and shales

The kaolins grade towards ball clays with additions of small amounts of montmorillonite to the kaolinite mineral resulting in increased plasticity, less refractoriness, and slightly off-white colors. Carbonaceous material generally occurs with the ball clays giving them a dark gray natural color. This color disappears as the carbon is oxidized during firing revealing the true fired color.

With increasing small amounts of iron compounds the kaolins or ball clays gradually change towards the buff-firing clays. Mineralogically the kaolins would grade towards flint and fire clays, the difference between the latter being one of compaction and hardness. Semi-flint clays are intermediate in the continuous series between flint and fire clays. The ball clays grade into plastic bond and plastic fire clays, a continuous series existing between all three on basis of increasing amounts of iron oxide and montmorillonite.

The aluminum hydrate minerals, gibbsite ($Al_2O_3 \cdot 3H_2O$) and diasporite ($Al_2O_3 \cdot H_2O$), occur with kaolinite forming a series grading from flint clays to bauxitic clays to diaspore. Because of the correspondingly higher Al_2O_3 content which is more refractory than SiO_2 and the fact that no eutectic exists between kaolinite and Al_2O_3, these clays are more refractory and are highly desirable for high grade refractories. The color is some shade of buff because iron hydrate is generally present with the aluminum hydrates.

Then, as the clay mineral mixtures shift to illite-rich deposits, the red-firing clays and shales develop. These are the least refractory clays because of the presence of K_2O. Presence of other impurity minerals in the red-firing clays, such as chlorites, may further lower the fusion point and affect the firing characteristics by shortening the firing range. Small amounts of montmorillonitic material in these clays as in the kaolinites also tend to increase plasticity and dry strength. Still another series develops by additions of calcium and magnesium carbonates to the red-firing clays to form the buff-firing calcareous shales and clays.

There are clays that have some extensively developed or desirable property, such as plasticity, dry and bonding strength, or firing range and temperature, that make them particularly suited for some specialized use. They then become known under some specific name, such as slip clays, wad clays, stoneware clays, sagger clays, etc.

CONCLUSIONS

Clays are composed essentially of clay minerals of the kaolinite, illite, and montmorillonoid groups which are complex in their structure and consequently have considerable variation in chemical composition. Clays, being secondary, further have considerable variation in the nonclay or associated mineral composition.

The clay mineral particles are of colloidal size, have a charge expressed as cation exchange capacity, and are essentially platy. This is probably at least partly responsible for the physical properties associated with clays.

Kaolinite and/or illite form the bulk of the ceramic clays, the former being the chief constituent of the refractory and white-firing clays.

Although high montmorillonite clays are not used as such in ceramics, presence of small amounts of montmorillonite have a considerable effect upon the properties of clays, both unfired and fired.

Because of their extensive use and variable occurrences, clays can be classified in many ways. The most commonly used bases are geologic, ceramic properties of fired color and refractoriness, and usage in some special product.

With increasing research activity on the mineralogical compositions and their corresponding effect on various properties of clays, it is becoming more and more possible to engineer a clay for a certain use. Considerable elimination of unsuitable clays can thus be achieved. However, the final selection of a clay is still empirical and has to be determined by actual test.

PROPERTIES OF CLAYS

W. J. KNAPP [*]

A large number of ceramic products is manufactured with clay as a constituent, or sometimes the only raw material. The success of the manufacturing operation is often highly dependent on certain properties of clay-water mixtures. It seems very desirable, therefore, to study certain property characteristics of clay with a view to possible correlation with manufacturing operations. It is the purpose of this paper to review, in a simplified manner, some of the present ideas on two properties of clay-mixtures: (1) plasticity, or workability, and (2) the effects of certain ion additions.

By way of introduction, it is interesting to review the physical nature of clay. Pure clay ($Al_2Si_2O_5(OH)_4$), or kaolinite, occurs in nature as a very fine grained mineral, most of whose particles are too small to be seen with the aid of an optical microscope. As examples, about three-fourths (by weight) of the particles of a typical ball clay are finer than one micron, and about 70 percent of the particles of a residual kaolin are finer than 20 microns. The development and availability of the electron microscope has given us a means for viewing the tiny clay particles; such studies have revealed the particles as thin, flat plates, most of them hexagonal in shape. The shape and size of the clay particles are important factors influencing the plasticity and other properties of clay-water mixtures.

Plasticity of Clay-Water Mixtures. The plasticity of a material may be defined, somewhat qualitatively, as the ability of the material to undergo permanent deformation (beyond that of elastic yielding) without failing. This means, of course, that the deformed body is not returned to its original shape when the deforming force is removed.

The plastic behavior of workable clay-water mixtures is well known. A theory has been developed by Norton (1948, pp. 236-241) to explain the mechanism responsible for the plasticity of clay-water mixtures, and some of the broad aspects of the theory are given here. In visualizing the nature of a clay-water mass, it is helpful to assume probable arrangements of the small clay particles in the mixture. The platelike clay crystals are believed to be found in stacked-up piles, or groups. East (1950, pp. 211-218) suggests that a possible arrangement of groups may be assumed on a basis of probability.

The particles are separated and surrounded by thin-water films. The water film between the plate-like surfaces is stretched down into capillary spaces, and the capillary forces of attraction tend to pull the particles together. However, it is also known that forces of repulsion act on adjacent particles (due to the presence of electric charges on the particles) and an equilibrium state is established wherein the repulsion forces are just balanced by the hydrostatic tension forces. When a plastic clay-water mass is subjected to an increasing load, it is initially deformed elastically, until, at the yield point, it then deforms permanently and plastically. The yield point is related by Norton to the holding together of the mass by the outer surface film, while the plastic

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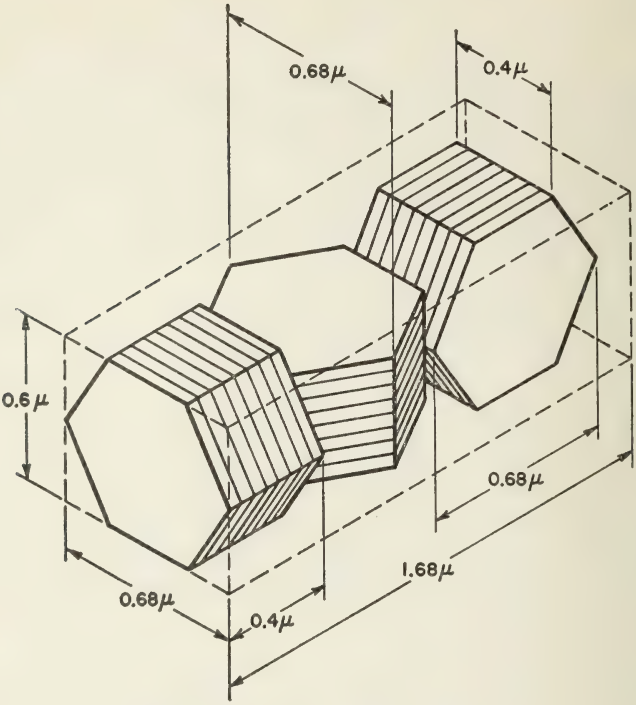

FIGURE 1. Plastic kaolinite structure.

deformation is believed due to the sliding of the plate-like particles over each other, perhaps lubricated by water films.

To obtain a quantitative concept of plasticity showing the effects of loading a specimen of plastic clay it is desirable to plot a stress-strain diagram.

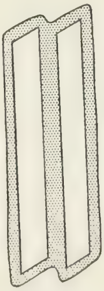

FIGURE 2. Two clay plates surrounded by a water film.

The region of plastic deformation, or extension, is shown by *ab* in figure 3. A workable clay-water mass should have a yield value (*a*) large enough to prevent the mass from deforming under its own weight, or by accidental loadings. The region or extent of plastic deformation or extension should be as large as possible, to allow formings to take

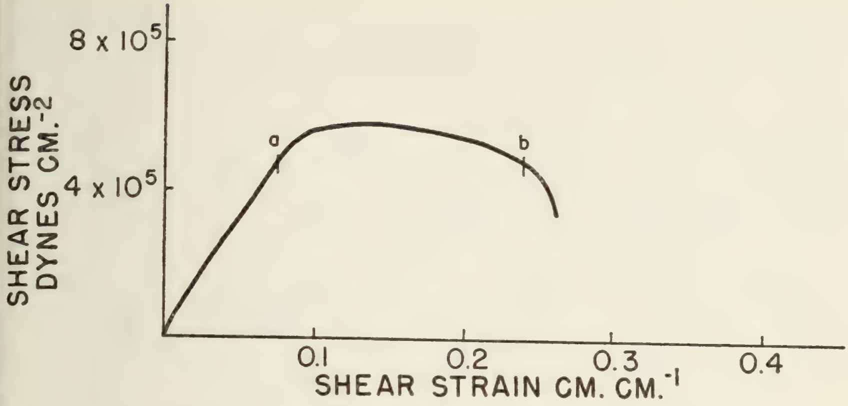

FIGURE 3. Stress-strain diagram for a clay-water paste.

place without rupturing the mass. Therefore, it may be appropriate to define workability as being directly proportional or equal to the product of the yield point value and the maximum extension.

As additional water is mixed with a relatively stiff plastic clay, the yield point decreases and the extensibility increases. However, these changes do not proceed at the same rate, and generally their product (i.e. workability) passes through a maximum value. This is a confirmation of the result experienced by anyone who has mixed clay and water (added in increments) by hand. The effect of addition of a wetting agent to a clay-water paste may be predicted; the wetting agent may reduce the surface tension of the water, and will thereby reduce the hydrostatic tension forces of attraction acting between kaolinite plates. This would result in a reduction of the yield point value and a decrease in workability. However, for some manufacturing operations, such as extrusion forming, a reduction in yield point value might prove beneficial in reducing power requirements. In other cases, however, the use of a wetting agent might not be of benefit.

It may be concluded that the plasticity of fine-grained clays, when mixed with water, will be greater than the plasticities of coarser-grained clay-water pastes; the apparent reason for this being the greater surface area in plate-to-plate interfaces in the finer-grained clays, and the smaller capillary channels between the fine-grained particles.

Effects of Certain Ion-Additions on the Flow Properties of Clay-Water Mixtures. As mentioned previously, the particles of pure clay, or kaolinite, are usually very small, and in fine-grained clays a large proportion of the particles may be smaller than 1 micron in the largest dimension. Since the maximum size of the colloidal matter is often arbitrarily named as 1 micron, we can expect clay particles to exhibit some of the characteristics of colloidal matter. Colloidal matter, and clays, possess a large area per unit weight. In the case of clays, the surface areas involved may exhibit considerable activity and attraction for ions. The ion attraction of the clay particle is believed due to the broken inter-atomic bonds on the fractured surfaces of the clay plates, or to the surface energy of the crystal lattice. Figure 4 shows a clay

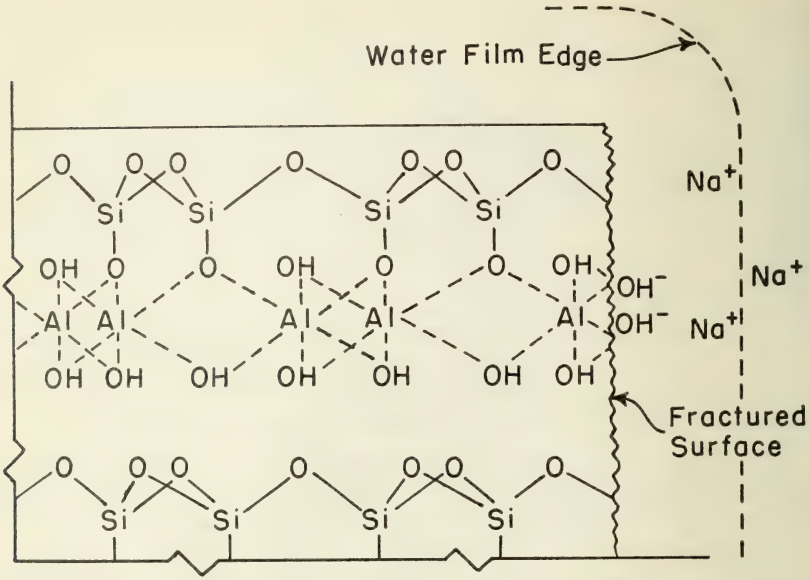

Figure 4. Fractured edge of a kaolinite crystal in water suspension.

crystal suspended in water in which OH^- and Na^+ ions are present. It is believed that the clay particle is surrounded by a tightly held film of water, and that a layer of rigidly held OH^- ions are located at the fractured crystal surface. There is found a more diffusely located cloud of positive counter ions (in fig. 4, Na^+) surrounding the particle. Some of the Na^+ ions are believed to be located outside the water film (at any instant), while others are within the film. Figure 4 represents this situation, and such a clay particle may be then discribed as a ''sodium clay,'' or ''CLAY-OH-Na.'' For such a particle, there is a definite electrical potential difference between that of the suspension medium and the edge of the particle water film—in other words, the particle is electrically charged.

The phenomenon of ion-exchange may occur; if certain other positive ions are added to a sodium clay particle, the new positive ions may replace the sodium ions as counter ions. For example, the zeta potential of a sodium clay is much larger than those of calcium or magnesium clays.

In the former discussion of the mechanism of plasticity of a clay-water paste, the equilibrium established between the repulsion forces and attractive capillary forces of adjacent plates was suggested. The forces of repulsion may be attributed to a large degree to the presence of electrical charges on the particles; therefore, the equilibrium state is influenced greatly by the type of counter ion present around the particles. If the electrical, or zeta, potential is large, we would expect the clay particles to be somewhat separated at equilibrium, giving a system which can be sheared readily, or one having a reduced yield point. In other words, flow may be produced more readily in a clay-water system if the particles are highly charged. For example, the viscosity of certain clay-water slips may be reduced by several hundred times by developing large electrical charges on previously low-charged particles.

In summary, certain counter ions in the clay-water system produce relatively large electrical charges on the particle-water micelle. In general, the univalent cations, as counter ions, produce larger electrical, or zeta, potentials than other polyvalent ions such as calcium or magnesium. Clays in the natural state are most often found to have calcium or magnesium counter ions around their particles. If sodium ions, for example, were caused to replace the calcium or magnesium counter ions, the clay-water paste would have a lower yield-point value. Recent manufacturing procedures in the structural clay products field sometimes include additions of sodium carbonate to clay-water masses which are formed by extrusion. One of the results of the soda ash addition may be the reduction of the plastic clay yield point with a reduction in power needed for extrusion. On the other hand, addition of an acid to a plastic clay may increase its yield-point value.

It should be emphasized that the facility of exchange of clay particle counter ions is influenced by several factors, such as the type of compound in which the additive cation is incorporated. For example, a sodium silicate or sodium carbonate may be effectively used to cause replacement of calcium and magnesium counter ions by sodium ions, but sodium hydroxide is relatively ineffective. A discussion of such ion exchange reactions is beyond the scope of this paper, but the interested reader is referred to the excellent work by Johnson and Norton (1941, pp. 189).

It can be seen, however, that the presence of ions in the clay-water system may affect several properties markedly, such as the yield point (which affects plasticity) and the fluidity. Additions of certain ions

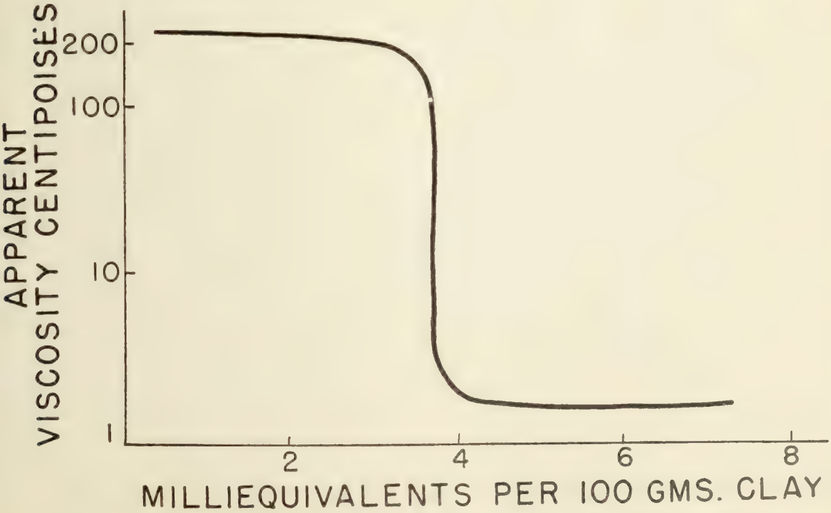

FIGURE 5. Viscosity of hydrogen clay-water slip on adding sodium ions.

may cause the development of desirable, or sometimes undesirable, characteristics in clay-water mixtures. Further information on this subject may be found in Norton (1952).

Conclusions. In reviewing the presently accepted ideas pertaining to the plasticity and ion exchange characteristics of clay, we are impressed with the importance of becoming acquainted with the nature and structure of clay particles. Further use of tools like the electron microscope will add more to our information on the nature of clays and will aid in the building of a foundation of understanding upon which explanations of the important properties of clays can be built. The properties of plasticity and yield points of clay-water mixtures are seen to be very dependent on the size, shape, and structure of clay particles. The electrical charge present on the clay particle-water micelle affects plasticity and flow properties markedly.

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MINERAL EXPLORATION AND WINNING OF CLAYS

By E. H. Wisser * and Mort D. Turner **

If the Pacific Coast ceramic industry keeps pace with the present growth in population and industry in this region, the sources of clay supply will not be sufficient to meet the demand and it will be necessary to look elsewhere for clay. The known California deposits of high-grade kaolin and fire clay are in the Alberhill and Ione-Lincoln areas, with smaller deposits elsewhere. These deposits are already deficient in super-duty clay although clay of lower refractoriness is in sufficient supply. Ball clay is not produced in California but is supplied from other states. Common red-burning clay for brick and tile is generally abundant in the vicinity of operating brick plants but new deposits will generally need to be found for new plants. Certain types of bentonite and fullers earth, particularly swelling bentonite, are in short supply and search is constantly going forward for new deposits.

Kaolin and fire clay were exposed at the surface in most of the areas where they are now being mined and this generally led to the discovery and exploitation of these deposits. At Lincoln, for example, younger lava hides much of the clay area; at Ione, soil, sandstone, tuff, and terrace gravel mantle the clay series in large part. With little doubt similar clay deposits lie completely hidden by overburden.

The secret of successful exploration for rare mineral deposits such as high-grade kaolinite and bentonite lies in elimination of unpromising areas and concentration on promising areas, which are always of limited extent. To find areas that are potential sources of commercial clay deposits, the occurrence and mode of origin of the deposits must be understood.

All of the high-grade sedimentary clay and most of the residual clay in California was deposited or formed during the Paleocene and Eocene epochs. Most of the red-burning clay for structural clay products is restricted to Quaternary alluvium and Mesozoic marine shale. A majority of the bentonite and fullers earth deposits in California are derived from beds of volcanic ash deposited in bodies of water in the Tertiary and Quaternary. The fact that these patterns of occurrence exist has been realized in a general way for a long time and they have been used to some extent as guides to prospecting for clay. However, the finding of new clay deposits and the more diversified use of known deposits in the future will in large part depend upon this and similar knowledge of the origin and occurrence of clays.

Commonly, clay is referred to by the commercial name. The major uses, in order of tonnage, are: heavy clay products, portland cement, fire brick, foundry sand binders, paper fillers and coating, petroleum industry (oil well drilling mud, filtering and decolorizing), and pottery and stoneware. These uses consume about 90 percent of the clay produced in the United States each year.

The utilization of a clay is dependent almost entirely upon the physical and chemical properties of the clay and these properties are, in most cases, a direct reflection of the clay minerals present. Kaolinite, for example, is almost always the dominant mineral in commercial deposits of high-grade ceramic clays, while illite is the major clay mineral group in many deposits of clay used for common brick and tile. Bentonite and fullers earth are made up largely of the montmorillonite clay minerals.

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ORIGIN OF CLAY

All clays are altered from other minerals. None are considered to be primary minerals formed directly from magmatic solutions or crystallized from molten rock. The various clays are the result of three general processes, subaerial weathering, subaqueous alteration, and hydrothermal alteration.

Subaerial or surface weathering takes place through the action of surface water containing small quantities of dissolved mineral and organic matter. It is especially active under tropical conditions where the warm, humid climate produces abundant plant life and the ground water is high in carbon dioxide (Bateman, 1950, p. 221). Weathering effects are most profound at the surface and grade down a few tens of feet irregularly into unaltered rocks. The size and shape of such deposits are controlled by the size and shape of the bodies of parent rock and by the depth of weathering. For these reasons deposits of weathered residual clay are usually flat tabular bodies, sometimes covering large areas. A clay deposit formed by the weathering of a pegmatite dike is long and narrow in shape and is usually deeper than the average weathered clay mantle.

Subaqueous alteration similarly results in flat tabular bodies but usually because the material being altered has been deposited as beds on the bottom of a lake or ocean.

Hydrothermal alteration takes place through the action of hot, chemically active water rising toward the surface from great depths. Because this water rises along permeable zones such as faults or geologic contacts, bodies of hydrothermal clay tend to extend to relatively great depth but are usually of only moderate lateral extent.

Each of these processes results in the formation of residual clay deposits, that is, deposits in which the clay mineral has not been moved from its place of origin. Deposits in which the clay has been moved are called transported or sedimentary deposits.

Transported clays are derived from residual deposits and are merely moved to a new position by the processes that move other sediments. Moving water is the usual carrier and most transported clays are laid down as bedded deposits in river flood plains, lakes, or the sea. Running water will not only transport solid material but will cause the particles to abrade each other so that the average particle size is reduced during transportation. When sediments are deposited there is always some sorting according to size and specific gravity, wherein the larger, heavier particles sink to the bottom and come to rest as the velocity of the stream decreases. As the slope of the stream bed decreases towards the mouth there will, in a general way, be a settling out of the coarsest fragments and then successively of finer and finer particles. Clay particles carried in streams are so fine that they settle out only where the water is practically stagnant, as in local backwaters of the channel or on flood plains where the water comes to rest after times of high water. Many of these poorly drained areas, especially in a warm humid climate, are swamps in which decaying vegetable matter may form beds of peat or coal and help to promote further weathering of the clays being deposited in the swamp. Such processes lead to the common association of coal and clay deposits, and under these circumstances the clay is commonly made up of the kaolin-group minerals. Where a river enters the sea, clay may be deposited in estuaries, lagoons, shallow arms of the sea, or in deltas. After the passage of considerable geologic time, shale is formed from these fine-bedded clay deposits. The clay fraction of river and flood plain deposits in temperate climates is usually made up largely of illite.

Most sedimentary clay deposits are lenticular, flat lenses pinching out in all directions. There is a wide range of purity in sedimentary deposits, but despite contamination by silt, sand, and iron oxide, much flood-plain and river-bottom material contains at least enough clay for the mixture to be used in the production of common brick and red building tile.

REGIONAL OCCURRENCE OF CLAY IN CALIFORNIA

California is divided into 11 geomorphic provinces, each with its own climate, clay occurrence, clay consumption centers, and system of transportation (Jenkins, 1938b).

The Sierra Nevada province coincides with the dominant mountain range of the state, which rises very gently from the Great Valley province on the west and culminates in a high crest near the eastern boundary of the province. The southern Sierra Nevada consists of an almost continuous mass of granite; in the northern Sierra less continuous masses invade metamorphic rocks such as slates, schists, and greenstones. During the early Tertiary, residual clay deposits formed over the low ancestral Sierra Nevada, but most of this clay has been eroded away and few of the remaining residual deposits have been exploited. However, the vast residual blanket of kaolin-rich soil and laterite furnished a source, in Eocene time, for the important transported deposits of refractory clay mined at Lincoln, Ione, and elsewhere from the Ione formation. The Ione formation crops out in a narrow, discontinuous band where the western foothills of the Sierra Nevada merge with the Great Valley of California (pl. 1).

The Great Valley of California, consisting of the Sacramento Valley on the north and the San Joaquin Valley on the south, is a great alluvial plain between the Sierra Nevada province on the east and the Coast Ranges province on the west. On the eastern side of the Great Valley, Eocene and later sediments dip gently below the center of the valley and reappear on the western side. In the flood plains along the Sacramento and San Joaquin Rivers, as well as along many of their tributaries, extensive areas of alluvium are now, or have been utilized for the manufacture of common brick, hollow tile, flower pots, and sewer pipe. These sediments are recent derivatives of the mechanical and chemical breakdown of the rocks of the Sierra Nevada and the Coast Ranges. The clays are typically sandy and red-burning.

The Coast Ranges province consists of a series of mountain ranges, 2000 to 4000 feet high, and intervening narrow valleys with a trend roughly parallel to the Sierra Nevada and the Great Valley. The rocks are mainly folded and faulted sedimentary rocks. Many of the valleys contain alluvial clays similar in physical characteristics and origin to the alluvial clays of the Great Valley. The clay deposits of the Niles alluvial fan in Alameda County and along Coyote Creek at San Jose are typical examples. The first fire clay mined in California came from the Mt. Diablo coal field in the central Coast Ranges and from Tesla where good refractory clay was mined for many years. These clays are in Eocene formations that are the western equivalent, at least in part, of the Ione formation. Marine shales of Jurassic and Cretaceous ages are the principal source of material for much of the brick industry in the vicinity of San Francisco and are a potential source of clay throughout the Coast Ranges. Deposits of residual kaolin and bentonite, a result of hydrothermal alteration of Tertiary volcanics, and marine bentonite derived from bedded volcanic ash, are also known and mined in the Coast Ranges province.

In northern California the Klamath Mountains, Cascade Range, and Modoc Plateau provinces have no known commercial clay deposits although the geologic settings suggest that clay deposits of some value could exist there.

South of the junction between the Sierra Nevada and the Coast Ranges are the Transverse Ranges which have a dominant western trend. Toward the west the mountains are made up of thick, folded sediments; toward the east they are largely composed of plutonic igneous and metamorphic rocks. In the Transverse Ranges several deposits of marine shale are being worked for brick clay, drilling mud clay, and clay for the manufacture of lightweight aggregates. A number of deposits of alluvial clay in river flood plains are being used for common brick and red roofing tile.

The Peninsular Ranges province is made up of a series of ranges and valleys trending northwest, structurally similar to the Coast Ranges but geologically like the Sierra Nevada. The main ranges are composed of granite intruded into metamorphosed sediments and volcanics. During the early Tertiary a mantle of kaolinitic soil and laterite formed over the crystalline bedrock and on the Cretaceous sediments in the western part of the province. In San Diego County at the same time several systems of pegmatite veins were deeply weathered. A few of the weathered pegmatites have escaped complete erosion and are potential sources of china clay. During part of the Paleocene and Eocene, erosion stripped the residual soils from higher land and clay and high-silica sands were deposited in the Temecula Valley and along the west side of the westernmost range of the Santa Ana Mountains.

Recent erosion has exposed the clay-bearing beds in a narrow, discontinuous strip from San Diego northward around the north end of the Santa Ana Mountains and south in the structural trough of the Temecula Valley. These beds furnish a major portion of the fire clay, sewer-pipe clay, and china clay produced in California. These deposits are especially well exposed near Alberhill in Riverside County and mining centers in this area. In addition to the red-burning Tertiary clays there are extensive deposits of Quaternary alluvial clays in many of the valleys, and especially in the Los Angeles basin, which are used for heavy clay products. Some of these deposits are along river flood plains but many are on the lower reaches of large alluvial fans.

The Mojave Desert and the Basin-Ranges provinces are regions of interior drainage except for a narrow strip along the Colorado River.

The occurrence of clay is very similar in the two provinces and quite distinct in occurrence and origin from the clay in the rest of California. The Mojave Desert is characterized by isolated mountain ranges of metamorphic and igneous rocks surrounded by broad expanses of desert alluvial plains. Playas (dry lakes) occupy many of the basins. In the Basin-Ranges province the mountains are higher and have a distinct northwest trend. In the basins of both provinces are late Tertiary and Quaternary lake beds. Thick and very extensive beds of volcanic ash that occur in the lake beds have been altered to montmorillonitic clay.

The environmental conditions, especially the chemical nature of the lake water, were important in determining what types of clay were produced (Millot, 1952). In different basins there are swelling bentonite, non-swelling bentonite, and fullers earth, with varieties of each type The best known lake-bed clays, from a commercial standpoint, are those of Owens Valley, Amargosa Valley, and the Mojave River basin. A major part of the clay production of the region and of California has come from the very late playa deposits of Rodgers and Buckhorn dry lakes. The clay makes an excellent drilling mud and is widely used by the petroleum industry in the state. Residual clays formed by hydrothermal alteration are known from the various provinces and, while they are all white-burning clays, there is a wide range of clay mineral composition.

The Colorado Desert province is the smallest of the California geomorphic provinces. It is a low-lying desert basin underlain by Tertiary marine or lake beds, in some places exposed by dissection and in others covered by alluvium. On the western edge of the region are extensive deposits of sedimentary clay which may prove to be usable in drilling muds and there are a few deposits of bentonite similar in origin to the bentonites of the Mojave Desert province.

From these descriptions of the geomorphic provinces and their clay deposits, several generalizations are evident. Red-burning clay suitable for common brick and other heavy clay products is abundant in the alluviated basins of the areas where rainfall and plant growth are sufficient to promote chemical breakdown as a major process in erosion. This is in striking contrast to the very sandy alluvium, with a very low proportion of clay, characteristic of the desert regions of California.

Red-burning marine shales are available throughout the outcrop areas of Mesozoic and Tertiary marine sediments, especially in the Coast Ranges, Transverse Ranges, and Peninsular Ranges.

EXPLORATION FOR CLAY DEPOSITS

As the clay deposits are gradually exploited, it will be necessary to explore those areas where clay outcrops are lacking, transportation is poor, or distances from points of consumption are greater than average. Most of the well-known centers of clay production in California were found because the clay cropped out or was encountered during the mining for other minerals. For example, many of the early fire-clay deposits were found because of their association with coal. The successful search for new deposits must be carried out in a logical manner. Basically the unpromising areas must be eliminated and exploration concentrated in the inherently promising areas. These decisions are usually based, either consciously or unconsciously, on geologic knowledge.

In addition to new discoveries, there are many rediscoveries of clay deposits that were abandoned for various reasons in the past. In some cases abandonment was caused by transportation problems which have since been solved by the development of new roads and equipment. Many deposits of good clay were captive pits and became idle when the operating company ceased to exist. Leads to such deposits can be found in many of the commodity reports of the Division of Mines (Aubury, 1906; Boalich and others, 1920; Dietrich, 1928) as well as the publications of other agencies.

Residual Kaolinite-Group Clays

Kaolinite may be derived from almost any type of rock if the conditions of alteration are suitable. In a given environment, rock high in aluminum and low in iron will, from a commercial point of view, yield a good kaolin-type clay, given sufficient time under the proper conditions. But equally desirable clay can form in some cases from a rock low in aluminum and high in iron. Economic clay deposits are derived from such widely divergent sources as crystalline, glassy, and sedimentary rocks. Most commonly, residual kaolinite deposits are found on granite, pegmatite, and arkosic sandstone.

In the formation of kaolinite from orthoclase feldspar, for example, the original potassium-aluminum silicate breaks down and combines with carbon dioxide and water to form potassium carbonate and silica, which are removed in solution, and insoluble kaolinite. Free quartz, limonite, and other impurities may remain behind with the clay mineral (Bateman, 1950).

Commercial residual kaolinite deposits are formed by both hydrothermal solutions and weathering. The following conditions must prevail for the formation of pure deposits of kaolinite by weathering:

1. Persistent weathering, under a warm, humid climate.
2. Formation of clay by weathering must be more rapid than its removal by erosion.

High-grade kaolin and fire clay in sedimentary deposits and residual deposits are closely related to the period of tropical climate general in California during early Tertiary time (Jenkins, 1943, p. 92). Most of the deposits are found near the shoreline of the early Tertiary sea or on remnants of the old continental surface that have been preserved from erosion. Such deposits are mined in the Sierra Nevada, Coast Ranges, and Peninsular Ranges.

Hydrothermal residual deposits of kaolin and related white-burning clays have been found in nearly all provinces and are related to volcanic activity which is a source for the altering solutions. Most of the deposits were formed from the late Tertiary to the Recent, although a few are much older.

Bentonite and fullers earth are also found in almost all parts of the state; in both fresh-water and marine beds deposited in the Paleozoic, early and middle Tertiary and in the late Quaternary.

Clays suitable to use as a base for oil-well drilling mud are limited to playa deposits of the desert and the playas of the very dry southern end of the Coast Ranges. Tertiary marine shale at Ventura is being used for this purpose.

When the climate of an area is not proper for the formation of pure kaolinitic soils by weathering the soils formed will usually be composed of a mixture of kaolinite, montmorillonite, and illite, and may under some conditions be almost entirely illitic or montmorillonitic.

In general, the weathered residual kaolin deposits in California were formed during early Tertiary time and provided the source material for the sedimentary kaolin deposits of the Paleocene and Eocene. Most of these deposits were destroyed by erosion but some remain as isolated remnants where portions of the Tertiary land surface have been preserved. Most residual deposits have been found buried under the Ione formation near the town of Ione and below the base of the Martinez formation near Alberhill and at other localities in the Santa Ana Mountains area. The mapping and projection of such surfaces to determine their original configuration will frequently lead to promising areas for prospecting.

Hydrothermal residual deposits result from the action of solutions usually related to volcanism. Although most types of rock are found altered, volcanic rocks, especially acid volcanics such as rhyolite, rhyolite tuff, and perlite, seem to be more susceptible to hydrothermal alteration.

In California, hydrothermal deposits are being mined at Little Antelope Valley in Mono County, Jawbone Canyon in Kern County, and at Hart in San Bernardino County.

It can be concluded from these facts and the general distribution of the deposits within the state, that the possibility of finding hydrothermal clay deposits is much better in areas of Tertiary volcanism. This is particularly true near the center of volcanism, which is the principal source of the hydrothermal solutions, and along lines of post-volcanic faulting, which furnish convenient channels for solutions to reach the surface.

Transported Kaolinite- and Illite-Group Clays

Transported clays make up the majority of commercial clay deposits. Clay forming in a soil mantle over large areas may not be present in sufficient quantities in any spot to be a commercial deposit, but, by widespread erosion and concentration by a stream or river system, large concentrations of clay may accumulate. Sedimentary clay deposits are usually found in areas where running water, which has deposited its coarser load upstream, has had a chance to stand long enough for the suspended clay particles to settle to the bottom. Such conditions usually exist in lakes, flood plains, lagoons, and quiet ocean.

As clays are transported long distances by running water they become mixed with other clays and fine non-clay material from other sources. Thus clay eroded from a residual deposit of pure clay is purest near the source and becomes increasingly contaminated during transportation. The pure clays, while usually the least transported, generally occur as small lenses in coarse, poorly sorted sediments. Typical of California deposits made up of clay transported relatively short distances are those near the towns of Ione in Amador County and Alberhill in Riverside County. The most typical characteristic of these deposits is the rapid thinning and thickening of the beds.

Kaolinite-Group Clay. All of the sedimentary deposits of kaolinite-group clay in California are found in Paleocene or Eocene sediments. Most of the deposits are made up of clay derived from broad watershed areas underlain by aluminous crystalline rocks, and were deposited either on land or near shore. These are the conditions that are found in the deposits on both sides of the Great Valley and along the flanks of the Santa Ana Mountains (Pask and Turner, 1952; Allen, 1929; Allen, 1941; Stauffer, 1945; Piper, et al., 1939).

Jenkins (1943, p. 92) points out that the environment of the Eocene (and Paleocene) was ''singularly different from the periods preceding or antedating it.'' The Eocene climate was tropical, relief was low, and conditions ideal for deep secular decay and advanced weathering. According to Taliaferro (1943, pp. 136-137) a contributing factor for the warm, humid climate of the early Tertiary was the removal by erosion of a large land mass between the present Great Valley and the Pacific Ocean. This permitted warm moist air to reach the mountains to the east. Some idea of the relative extent of land and sea in the early Tertiary may be gained from a paleogeographic map such as the one prepared by Reed (1943). From the evidence of plant fossils the foothill area of the Sierra Nevada had a climate much like the present climate of some areas of southern Mexico (MacGinitie, 1941).

Although locally conditions may have been favorable for the formation of kaolinite by weathering before and after the early Tertiary, climate and erosion do not seem to have been in the right combination to allow large areas of pure kaolinite to form and be preserved in commercial deposits. Known deposits of good china clay and refractory clay in California are scarce in comparison with deposits of common clay. They are almost wholly confined to two areas, the Ione formation belt along the eastern margin of the Great Valley and the Alberhill district in Riverside County.

The middle Eocene Ione formation crops out discontinuously for about 200 miles and consists largely of siliceous gravels, clayey siliceous sands, clays, and lignite beds.

At Lincoln, an isolated remnant of the Ione formation, protected from erosion by a lava capping, underlies a low hill. The clay is continuous over 4 square miles, to a depth of 100 feet beneath the capping. About 40 miles southeast, at the town of Ione, the clay belt is about 12 miles long, up to 2 miles wide, and at least 250 feet deep. In other portions of the Ione formation belt the Ione sediments have been eroded off, covered deeply by later sediments, or else exposed to a much less limited extent than at Ione or Lincoln.

At Alberhill, Riverside County, high-grade clays occur along the Temescal Valley in the Paleocene Martinez formation, which crops out in a belt about 12 miles long and 2 miles wide. The clay series is up to 400 feet thick, and contains lignite, various types of clay, coarse clayey silica sand, and shale. The clay beds are less continuous than those of the Ione formation because of folding, faulting, and erosion. Prospecting and mining are difficult as the individual clay beds have a large range in composition, because of varying conditions of sedimentation during the Paleocene. Alternation of beds of clay and coarse sand indicates that conditions of quiet sedimentation marked by deposition of clay from nearly stagnant water were preceded and followed by times of freshet or strong tidal currents, which brought in coarse material.

Exploration for additional deposits of the type encountered at Ione, Lincoln, and Alberhill should be concentrated on areas where early Tertiary sediments were laid down in swampy basins adjoining regions of deeply weathered aluminous rocks, especially where lenses of coal or lignite occur. The presence of sediments rich in iron oxide and quartz may also indicate promising areas. The general distribution of early Tertiary sediments in California is indicated on the geologic map of California (Jenkins, 1938a), but the details can be worked out only by careful geologic mapping.

The areas underlain by sediments that are possibly clay-bearing, may contain certain horizons and certain structural features that are more favorable for prospecting than others. In the Buena Vista area of Amador County, for instance, all of the commercial clay bodies are in one horizon, the lower member of the Ione formation.

The only super-duty fire clay in this area, as well as in the surrounding areas, is restricted to the base of the lower member and even at that horizon it is only on the flanks and crest of a covered bed-rock ridge. Prospecting carried on for super-duty fire clay in this area can thus be concentrated in the limited zone along this bed-rock ridge (Pask and Turner, 1952).

Illite Group or Common Clay. In temperate climates most soils are made up largely of the illite and montmorillonite groups of clay minerals.

It is these montmorillonite- and illite-bearing soils that furnish the source for most of the sedimentary deposits of red-burning clay used for heavy clay products. They are a major constituent of the alluvial material that is carried by most streams and rivers. This material is ultimately deposited in flood plains, lakes, and in the sea.

With few exceptions, deposits of common clay in California are of two general types, Quaternary alluvium and older marine shale. Only a small part of the alluvium one sees in nearly every valley and basin is suitable for ceramic use. Most alluvium is far too coarse or does not contain a high enough percentage of clay. This is especially true of alluvium in arid regions where mechanical breakdown is the major erosional process.

Typical of the Quaternary flood-plain clays are those used for common brick that are mined along the Sacramento River at Sacramento, along the San Joaquin River near Stockton, and from the banks of Coyote Creek near San Jose. Typical of the marine shales are those mined for brick from the Cretaceous Chico formation at Port Costa, the Jurassic Knoxville shale at Point Richmond and McNear's Point, and from the Miocene Modelo (Castaic) formation at Castaic.

Many deposits are the result of a combination of sedimentary deposition and residual weathering. Frequently clay will be further acted upon in such a manner as to change the original clay minerals to different clay minerals after deposition and before the clay is covered by later sediments. Sometimes these changes are desirable, from the standpoint of industrial usage, and sometimes not. This is especially important in clays which are deposited in fresh-water swamps and in the ocean. In swamps abundant plant acids can further leach and purify the clay and some of the best fire clay is a result of such conditions, while much of the clay deposited under marine conditions is converted to the illite types (Millot, 1952, p. 109).

Alluvial clay is most likely to be found where running water, with clay in suspension, slowed down sufficiently to allow the clay to settle out. Such areas are usually in flood plains, lake basins, the lower end of alluvial fans, and drowned valleys that have been filled in by streams with relatively low gradients. Most geologic maps indicate areas of alluvium although the alluvium is not generally subdivided sufficiently to indicate a potential clay deposit. An exception is the modern soil map. An example of a soil map that could be used to determine areas of potential brick clay is the soil map of Sacramento County (Weir, 1950). The clay pit of a long-established brickyard is shown in the Sacramento silty clay loam (Weir, 1950, p. 47, sheet 15A). Prospecting for common clay in that area would logically start with investigation and tests of the Sacramento silty clay loam elsewhere in the county, as outlined on this map. If, because of ownership, accessibility, or physical characteristics, none of the deposits of that particular clay were suitable, then prospecting could be carried to similar clayey sediments also shown on the map.

Marine shale has proven to be very satisfactory as a ceramic raw material in a number of California plants. Prospecting for similar clay could begin with an investigation of outcrops in the immediate area along the same bed and then of outcrops of the same formation in nearby areas. With the aid of geologic maps discontinuous outcrops and isolated areas of a given formation can be found without a time-consuming search throughout an entire region. Some formations are made up of two or more rock units or facies, for example shale and sandstone. In this case a study of the report accompanying the geologic map may indicate where in the formation the clayey sediments are present and thus suggest areas of more promise.

The marine shales used in the San Francisco area for their clay are all of Cretaceous or Jurassic age; the shales used in southern California are Tertiary, with one exception, which is Cretaceous. There are few shales older than Jurassic that would be satisfactory for brick making, but, from the evidence of presently operating pits, any of the younger formations are possible clay sources.

A separate commercial type of sedimentary clay is the oil-well drilling mud found in the playas of the desert areas. This is a mixture of illite, chlorite, and fine sand deposited as lake beds by flood water that periodically covers the playa surface. The greatest production of drilling mud from California has been from Rodgers and Buckhorn dry lakes in Kern and Los Angeles Counties. A satisfactory drilling mud must have sufficient weight when mixed into a slurry with swelling bentonite to counteract oil, gas, or water pressure encountered in drilling. In addition it should have a low permeability so that the mud will build up a thin, tough, impervious skin on the inside of the well, thus casing the hole. Production of these playa lake muds in California has increased from 55,000 tons in 1919, with a value at the pit of $1.58 per ton, to 107,000 tons in 1950, with a value of $4.10 per ton (C. N. Schuette, personal communication).

Montmorillonite Clays

Commercially valuable deposits of montmorillonite are usually derived from glassy volcanic rocks by residual alteration. Although many soils are made up of montmorillonite in large part, such occurrences are never pure enough to be mined. Bentonite and fullers earth (rocks composed primarily of the montmorillonite clay minerals) are usually found as beds in marine or lake sediments where volcanic ash has fallen or been washed into a body of water. The montmorillonite was formed by the alteration of glass shards and much of the crystalline material in the ash. A few bentonite deposits were formed by hydrothermal alteration of volcanic rock—usually the glassy varieties. Such deposits are similar in shape to hydrothermal kaolin deposits in that they have irregular, and limited, horizontal dimensions and extend to great depth vertically. Because both kaolinite and montmorillonite may form from the same type of glassy volcanic rocks by hydrothermal action, it is probable that the clay mineral formed is related to the composition and acidity of the hot water percolating through the deposit.

There are three general types of montmorillonite rock: (1) swelling, or gel-forming, bentonite capable of the adsorption * of many times its weight in water and therefore of swelling to a gel and becoming extremely plastic, (2) non-swelling bentonite which swells to only a limited extent but is highly plastic and (3) fullers earth which does not swell and has little or no plasticity.

The industrial value of swelling bentonite is dependent upon its gel-forming properties so the primary uses are in drilling mud and foundry sand. Important deposits are being worked near Hector in San Bernardino County and Idria in San Benito County; however, most of the swelling bentonite used in California comes from Wyoming. Non-swelling bentonite, after proper acid treatment, and fullers earth in its natural state, have the ability to remove colors and odors from mineral and vegetable oils. In addition certain of the bentonites are used as catalysts to promote cracking in the refining of petroleum. Extensive deposits of non-swelling bentonite have been worked in the Amargosa Valley in Inyo County, and in various parts of San Bernardino, Kern, and San Diego Counties. The only fullers earth deposit being worked in California now is near Olancha, Inyo County, but deposits in Kern and Solano Counties have been worked in the past.

As with kaolin and common clay, bentonite and fullers earth should be searched for where the environment during the past was favorable for their formation. Conditions were suitable for the formation of montmorillonite clays during the deposition of the early Tertiary marine beds of the Coast Ranges and the Peninsular Ranges, especially of the Eocene Kreyenhagen formation (Jenkins, 1931), and also during the formation of the late Tertiary and Quaternary lake beds of the Mojave Desert and Basin-Ranges provinces. These are the areas where there is the greatest chance of discovering new deposits. In searching for deposits the geologic setting of the known deposits should be studied, and available geologic maps of the areas to be prospected

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* Adsorption is the action of a body or molecule in holding a gas or liquid on its surface; absorption is the action of a body or group of molecules in incorporating a gas or liquid into itself; absorb or sorption are general terms to cover both actions.

should be consulted to determine where possible clay-bearing beds crop out. Bentonites derived from volcanic rock by hydrothermal alteration will be controlled by the same conditions as the hydrothermal kaolin deposits and should be searched for in the same manner.

DEVELOPMENT OF CLAY DEPOSITS

When a clay deposit is discovered or suspected to exist it is desirable that the extent of the deposit and characteristics of the clay be determined before too great an investment is made. Too often it has been found that surface weathering and leaching change the characteristics of clay in the outcrop so that it seems very satisfactory for some particular use, but when the clay is mined at depth it does not fulfill the requirements. In addition, the possibility that a clay lens does not extend as far as one might desire is another hazard. It may pinch out, be faulted off, or have been cut off by erosion at some time in the geologic past. Hydrothermal deposits of clay are especially unpredictable in extent and character.

It is important, therefore, to obtain as much information as possible about a deposit before beginning to mine it. This is usually done by first making a detailed geologic map of all the exposed rocks. Isolated exposures of clay in stream beds or road cuts may lead directly to discovery of a commercial clay bed. More often, mapping of beds that overlie a clay series in adjoining areas may suggest clay at depth in the area being explored. Also a knowledge of the regional structure may permit the projection of known clay beds under the cover of overburden. The next step may be trenching, if the overburden appears shallow, or, if a greater depth is to be reached, the use of auger, churn or diamond drills may disclose additional information. With the auger and churn drill, cuttings from the hole are recovered and can be studied; with the diamond drill, a core of the rocks traversed is obtained. Exploration and development of deposits is comparatively cheap, because most clay is mined today only in open-pit operations. This limits exploration to a depth of a few hundred feet at most.

As with cost of exploration, the cost of mining, especially of brick clay, must be kept low. Most deposits are mined by open-pit methods similar to stone quarrying. Hand methods were used for small deposits; but with increased cost of labor, and the development of modern excavating equipment, power methods have become the cheapest even for comparatively small deposits. In the larger clay pits the clay is taken out in one or more benches, drilling and blasting sometimes being necessary. Such equipment as rooters, bulldozers, carryalls, power shovels, and pay loaders all find use in clay mining, with the final hauling from the pit to the railroad, or to the clay plant, by truck.

Stripping of overburden is usually necessary except in deposits of brick clay where the upper layers, especially the soil, may be a very desirable raw material. Overburden is removed by much the same methods as those used to mine the clay beneath. The amount of overburden that can be removed in order to mine a clay deposit by open-pit methods depends upon the area, and the thickness and value of the clay. In a large high-grade clay deposit the ratio of thickness of overburden removed to thickness of clay mined is as high as 7.5 to 1.

Where the overburden is too thick to permit its removal for open-pit mining, and where the clay deposit is of sufficient size and value, underground mining is employed. With flat-lying clay beds, mining methods are similar to those used in coal mining. At the Jones Butte mine near Ione, parallel drifts (horizontal workings resembling small tunnels) 20 feet apart were run to the limits of the deposit. Retreat was then made by slicing a 5-foot cut from each side of each drift, starting at the limits of the deposit and retreating toward the main haulage way. This left a pillar 5 feet wide to support the rooms while the retreat was in progress.

The pillars were left standing, so that the minimum extraction of clay was 75 percent of the total. Where the roof was strong enough, the extraction could be increased by pillar robbing (Dietrich, 1928, pp. 53-54).

Underground mining is not practical in the Ione area now and is only active at Tesla, where a sand-clay mixture for foundry sand is mined, at Olancha, which is the sole source of California fullers earth, and at Hector, where two companies mine swelling bentonite by underground methods.

CONCLUSION

The key to the finding of new clay deposits is an understanding of the occurrence of the known deposits so that this knowledge may be projected into new regions and areas favorable for prospecting may be outlined.

There is no substitute for firsthand knowledge and experience in exploring for clay, but even the most experienced prospector will find a wealth of information available in the published literature. As the geology of California becomes better understood, the location, history, stratigraphy, and structure of promising areas will increase. Those prospecting for commercial clay deposits should keep close contact with the work of stratigraphers, paleontologists, and geologists, even though their activities may seem unrelated to exploration for clay deposits.

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CLAY TESTING

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In the discussion of clay testing, it may be of greater interest to know the reasons and the basic ideas for clay testing than the exact physical operations of the testing. The tests made at Gladding, McBean & Company are based on two factors: the type of clay being tested, and its ultimate use. Commercially, there is not much point in making tests only for classification purposes. The emphasis is on tests for determination of the clay's use. The use divisions to be considered, then, are: whitewares—either pottery, china, or tile; refractories, heavy or structural clay products, and uses outside the ceramic industry The types of clays that are tested are kaolin, ball clay, plastic refractory clays, non-plastic refractory clays, low-grade fire clays (usually these clays are semi-plastic, but sometimes have fairly good plasticity), and filler clays. ''Filler clays'' is not a very good term—actually it refers to clays that are mined locally from surface deposits of fairly recent origin and were once considered as fillers, especially in the ''heavy clay products'' bodies. They are now no longer regarded particularly as fillers, because they perform a very important function in fluxing bodies.

Whiteware Clays. In testing whiteware clays, either kaolin or ball clay, for use in pottery, the following tests are employed. A washing test is made on a 200-mesh screen to determine the amount of spotting impurities as compared to a standard. Bars are made of the raw clay, or the sample is mixed with equal amounts of flint clay. The dry strength is determined. The bars, without silica, are fired at various temperatures to determine the approximate maturing range. The color of the bars is checked.

If these first tests indicate that the clay is promising, a laboratory body is made using standard materials and replacing a constituent already in use with the material to be tested. It is usually simpler to first make a casting body, because it requires less time and work. Such a procedure also introduces the problem of electrolyte characteristics, which are important. In preparing the slip and casting ware and bars from it, the workability and necessary electrolyte additions are determined. These factors may not show up very accurately in laboratory tests, but clays difficult to handle usually can be discarded at this point unless there is some special reason to test them further. The casting rate is determined and is considered more important in china than pottery bodies. A knowledge of the dry shrinkage and strength is desirable and determinations are made on cast bars. Fired shrinkage, absorption, and strength are measured on cast bars fired at normal kiln temperatures. The fired color of the body with several glazes is also determined. If the tests still appear promising, then the glaze fit is ascertained by running autoclave, thermal shock and chipping tests.

If the casting results appear promising, the clay is checked in a jigger body. Again, the same tests are carried out—workability, necessary electrolyte additions, dry shrinkage, dry strength, fire shrinkage and strength, fired color with several glazes, absorption and glaze fit.

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If the results still appear to be promising, a pilot batch is tried in the plant. However, the pilot batch generally is not made until an actual substitution in the current body is being contemplated, since such tests are too expensive for purely informative purposes. It is felt that the ''pilot scrap'' is necessary in making the pilot batch because the properties of test bodies, with and without scrap, may be entirely different. Some bodies do not work up well with scrap, and some are more or less plastic with scrap. The normal procedure consists of making up a batch, allowing it to stand and partially dry to duplicate scrap obtained in the plant, and using it in the plant test batch in quantities comparable to the usual plant batches.

Results of this first batch must be carefully assembled as the body moves through the plant, preferably by a representative of the control department, since erroneous conclusions may be drawn by relying entirely on busy plant personnel to do the reporting. The resulting ware is thoroughly examined for appearance, and checked for fired color, absorption, glaze fit, glaze blistering, and chipping resistance.

If the first pilot batch appears satisfactory, the next step is a one-day run in the factory. If the pilot batch run itself required almost a day, a run of several days may be necessary. In any event, the steps are taken very gradually in order to avoid any unforeseen difficulties. During this test, the body is again observed very carefully through the plant and notes are made of the various operator's comments. If the first pilot batch is substantiated, then a large pilot run of one or two weeks duration is made. During this time as little mention as possible is made to plant workers about the fact that a test run is going through, although the foreman must keep a close check on their comments and the results that are being obtained. It again may be desirable to have someone from the control department conduct special work on this pilot run. It has been found that caution must be used as employees are apt to obtain misleading results with experimental batches due to more careful work when under close observation. If this run appears promising after evaluation and discussion of the results on the ware, it may be decided to make still another 4- to 6-week test through the factory. Generally, it takes about this period of time for real difficulties in scrap reworking to show up in the ware. The time lag in build-up of plant problems that results from use of scrap can be very deceptive and confusing and may take several weeks.

After the clay is approved for normal whiteware production, a control check is obtained on every lot or every carload that is shipped to the plant. This check will consist of a cleanliness and a lignite test, both of which are ascertained by washing on a 200-mesh screen; and color tests on some materials, made by firing a small sample. These lots or carloads of materials are also checked by introducing a representative sample into a standard body and comparing it with a standard approved lot of the same material. Whenever possible, this control testing should be entirely completed before the incoming material is approved for use in the plant. This type of test is made on all whiteware materials. A considerable amount of work is necessary, but it has been found that rejection of material on the basis of these tests has avoided the possibility of very heavy factory losses which could have otherwise occurred.

The testing program is about the same for china and earthenware bodies although additional checks are included for the former. Thus, extreme care is taken with color and shrinkage tests. Variations in shrinkage can have considerable effect on problems of decoration. Translucency of the china body is checked with a standard light source and photo-electric cell unit. The thermal shock resistance of china bodies is checked frequently because it is felt to be more critical in this type of body than in pottery. The substitution of a new clay in china bodies is done with great caution since it has been found that a clay may work in some bodies and be almost impossible to handle in others. Furthermore, it is found that a clay will generally work in both earthenware casting and jiggering bodies, but not always in china. There are some clays—quite satisfactory in a jigger-body—that make slips so difficult to adjust by electrolyte addition that they easily become gelled, resulting in higher shrinkage. In some cases the control of this condition does not seem possible with our present state of knowledge.

Tile bodies are checked closely for cleanliness of all materials, because unsightly spots tend to show up on glazing. Although the same applies to some extent to china bodies, the batch is ground so fine that most of the spotting materials are disseminated. Probably factory contamination is more of a problem than body-spots in china. When preparing tile materials, the nature of the clay body is less vital than the conditions under which it is used. Testing, then, must be done under plant conditions. The pressing characteristics and wet and dry strength are noted. Accurate data are difficult to obtain, but a great deal can be learned from the observations of the pressman and control man. After firing in production kilns, shrinkage, warpage, and wedging are measured. The bodies are then glazed with several glazes and tested for appearance of glaze color, autoclave resistance, thermal shock resistance, modulus of rupture, absorption, and sometimes for cutting characteristics. This last test is necessary since some tile bodies are so brittle that the tile-setters do not like to handle them.

Refractory Clays. In refractory clay testing the most common method for elimination of unsuitable clays is the Pyrometric Cone Equivalent test. If a large testing program is in progress and a high-temperature kiln is available, then this method is simplified by placing lump samples of all the clays in the kiln and firing to approximately 3000° F. The low refractory clays will melt, and the value of the good ones will be indicated. After this firing test, the regular P.C.E. test is performed on the most promising samples. If the color is bad in the P.C.E. sample, or if the clay comes from a known high iron bearing area, the iron oxide content is checked. This procedure is necessary, for with some of the clays from the southern California area, materials have been received whose P.C.E. ranged from 33 to 35 but which had so much iron oxide that they were unusable in a salable product.

If these results are promising, several procedures may be followed. If there is no immediate use for the clay, dry pressed or stiff mud bars, or both, are normally made up, and determinations of the dry strength, dry shrinkage, fired strength, fired shrinkage, and fired absorption are obtained. If possible, several firings are made; for instance, cones 10, 15, and 20. If the type of clay is familiar or if just one fire is desired, the samples are placed in one of the refractory tunnel kilns, usually at cone 15. These sample bars are first examined for color, and for iron spots, because some clays contain rather large coarse chunks of iron spot materials. The iron spots are objectionable from the standpoint of appearance in the brick although the quality may be unaffected.

If these preliminary tests indicate that the clay is only suitable for a grog, a sample is calcined in a laboratory kiln with a very fast heating and cooling schedule and used to manufacture laboratory batches of brick. If it is indicated that the clay may be used raw as a bond clay, it is tried in laboratory batches of standard mixes which are tested for strength, shrinkage, and any other characteristics of interest. Whenever possible, laboratory batches are made up on production presses. However, if a great number of samples are to be checked, or if the volume of any given sample is small, a laboratory press may be used.

Satisfactory results of all those tests lead to plant tests using normal plant operating procedures. Brick from these tests are then checked to determine whether they conform to standard A.S.T.M. specifications. If the results are particularly promising we then may have Mellon Institute make a complete series of tests. This is only done, however, when the plant test has actually had a production run from a quarter to half a day.

If results are still promising, then the procedure is somewhat the same as in the case of whitewares. A plant test of about 5000 to 25,000 brick depending on the existing results, is authorized. Further satisfactory results will call for a production run of about 50 or 100 thousand equivalents. At this point, with continued good results, the clay is accepted for normal production. Rather frequently clays are found that are not too satisfactory by themselves but are usable as a small portion of a production mix. In such cases, the testing will normally be about the same, although perhaps not quite so elaborate a program as with the production runs.

Clays for Structural Clay Products. The types of clays tested for heavy clay or structural clay products will vary considerably. They may be refractory, semi-refractory, or ''filler'' clays.

For face brick, roof tile, and floor tile, the raw clays are first made into bars by the stuff mud method. The bars are fired in production kilns and checked for color. This is probably the most important characteristic. If a usable color cannot be obtained at normal temperatures, the clay is usually worthless. However, if it does have some special properties, it may be used as a small proportion of a mix. In this case, nevertheless, the check on color is still most important. The bars are then checked for drying and firing shrinkage. If the clay thus appears promising, some of it is introduced into a factory mix. Incidentally, our desire on body mixes is to keep drying shrinkage at a maximum of 5 percent, and firing shrinkage at a maximum of 10 percent, or lower if possible. These figures actually are higher than preferred, but seem to be necessary limits for the available clays. The saturation coefficient is checked on the raw clay and also on the mixes. It is essential that the saturation coefficient is satisfactory if the product is to be soft fired.

In order to obtain specific colors normally, the drying characteristics are checked. The test of this particular property is rather crude but has provided some very helpful information. Results cannot be interpreted in terms of absolute values, but can differentiate the good clays from the poor and in-between clays. A 1- by 1- by 7-inch bar is laid on two steel wedges fixed firmly to a base on a 5-inch span. Then a 2- by 2- by 1-inch piece of steel is laid, with a 2- by 1-inch face down on the top of the bar, at the center of the span. The whole assembly is placed in the dryer (the one used at Gladding, McBean & Company operates at 280° F., with natural draft circulation, and combustion gases passing through the dryer) and allowed to dry. After drying, the clay is classified as an A, B, C, or D drying clay, depending upon its appearance: A, not more than possibly one crack among four bars; B, a couple of cracks; C, three or four cracks; and D, all four bars cracked longitudinally as well as transversely. Clays of the D type must be used with extreme caution and mixed with large proportions of clays with good drying properties. It may be noted that nearly all of the ''filler'' clays in this area fall into the D drying classification. Differential thermal analysis tests showed some correlation in that all of the local ''filler'' clays seem to be essentially illitic in composition rather than kaolinitic. This also holds true for the central California and Washington clays. Only one exception has been found so far—a Washington clay that seems to have a considerable amount of illite but still possesses good drying characteristics. This clay, however, is also rather different in its other characteristics.

Attempts are made to attain a dry modulus of rupture on heavy clay products mixes of 300 to 400 pounds per square inch. If the value is not this high, the addition of lignin compounds is considered to build up the strength and avoid loss in handling. Fired strengths required will depend on the particular material. For a sewer-pipe body, a minimum fired strength of about 3000 P.S.I. modulus of rupture is required. The same value is satisfactory and desirable for face brick, roof tile, and floor tile. Lower fired strengths can be tolerated for face brick. Perhaps an absolute lower minimum may be around 1500 P.S.I.

Greater care must be taken in testing clays for sewer pipe bodies than for face brick, roof tile, and floor tile bodies. It has been found that the properties of the plastic refractory, semi-refractory, and ''filler'' clays definitely have to be balanced in order to obtain good drying and firing characteristics. Frequently, the tests are made by representing the three types of clays on a tri-axial diagram. The amounts of the different clays in a mix are varied, normally testing only one unknown clay at a time. In case of extensive development work two unknown clays may be tested at one time to expedite matters. With overlapping of tests and proper interpretations, his procedure seems to be satisfactory. Drying tests on the sewer-pipe mixes are found to be rather helpful. Definite specifications have to be met. Hydrostatic tests are made on sewer-pipe mixes and have been found to be helpful. Practically no correlation between absorption and hydrostatic resistance has been found since the hydrostatic resistance of a body seems to be determined by the physical characteristics of the clays used in the mix. Very fine-grained plastic clay seems to aid in reducing permeability and increasing hydrostatic resistance.

Clay for Other Uses. Ceramic laboratories usually are not equipped for the type of testing necessary for clays to be used outside of the ceramic industry. One example is in connection with paper clays whose principal requirements are a very fine grain size, high reflectance, especially low viscosity for heavy slips, and absolute freedom from grit. Normally, each paper company has certain specifications upon which they insist. The emphasis of these specifications is placed on those tests which are most satisfactory for their purposes. Therefore, such tests may not be a perfect index of a good paper clay, but they are an index of a good clay for that particular company or operation.

About the only way to determine whether a clay will be satisfactory for use as a rubber filler is to actually compound it in a rubber mix and run the types of tests that the rubber industry uses. This is one of the most complicated clay testing businesses, inasmuch as various clays demand different kinds of compounding in the rubber. The companies selling rubber filler clays have had to build up large rubber testing laboratories in order to develop the proper usage for their materials and to give their customers the type of technical assistance that they require.

TESTING OF CLAYS

L. H. Lohman *

Clay testing methods are of interest to the practical production man as a tool for promoting uniform quality in the ware and to identify the properties of raw materials that may be favorable for the improvement of existing products and the development of new ones. Practical clay testing, therefore, is divided into two categories: (1) the control testing of materials in everyday use; (2) the testing of clays for indication of mix and process changes and preparation of new mixes and processes. The tests to be discussed are those commonly used for control testing.

Effective control testing must be expedient to the point that something is done about variations in clay either before or during their early stages of processing. Without this expediency, such testing merely records the details of an unsuccessful production technique. The timely sampling of clays can do very much to aid control testing by virtue of giving more time in which to run tests. Drill-core sampling ahead of mining operation, sampling during mining, and during stock piling of clays is of course an advantage over sampling at the bunker or batch car in the plant.

Although it is not a method of testing, the close observation of clays at any point in the process or during mining can be mentioned as a crudely effective control. Based on experience the notation of color, texture, fracture, feel, and slaking ability can be used as indications of the quality. It is not at all unusual for an experienced mining or plant man to be able to tell more about clay by looking at it than can be determined by several tests. Such observation is often aided by the use of wash tests to separate coarser impurities from the clay. After washing, the quantity of impurities may be easily determined and various constituents identified. Acid may indicate calcium or magnesium as the carbonate, although this test is not always dependable.

Probably the most universally used control test for clays is the determination of fusion point. In general, standard procedures recommended by the Orton Foundation and the American Society for Testing Materials are followed in the determination of pyrometric cone equivalents. Even in branches of the industry that are not primarily concerned with the ultimate fusion of clay, P.C.E. is still an effective control test, for the reason that impurities almost invariably affect the fusion point of the clay. It is rather unfortunate that the pyrometric cone equivalent test, even though standardized, is still a rather inaccurate test at times, especially in checking data between one laboratory and another. The difference in methods of preparation of samples and actual schedules of firing, often lead to results that do not agree. A considerable amount of work has been done toward the use of a quicker test than the standard P.C.E. determination. It has been approached in several ways by faster heating schedules, larger furnaces and removable stools to allow the pulling and placing of more plaques. In one method, clays can be tested at a rate of one unknown every 3 minutes

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in an oxy-acetylene furnace; the results are quite satisfactory for control purposes, but appear to run about ½ cone low.

Another method of control testing of clay is the testing of plasticity. Probably all the methods of tests for plasticity do not present too clear a picture of the forming ability of clays. Many different methods are employed to test plasticity: the general feel of the clay; the Atterburg plasticity test, which is the determination of differences in water content of the clay at various consistencies; dye adsorption, which is based on the ability of colloids to adsorb dye; and the determination of viscosity, which is a measure of resistance of flow of clay slurry. Viscosity is not a measure of plasticity, but seems to parallel plasticity. The Vicat Needle test is another method, consisting of dropping a calibrated needle into a mass of clay and measuring the depth of penetration. Various other devices set up stresses on a clay to measure the point at which rupture occurs on deformation. Most of the above methods may be used in control testing since they are relatively fast. In general, the determination of water of plasticity by hand working to a given consistency and determination of water content at this consistency is a reasonably accurate measure of plasticity for control purposes.

Drying and firing tests are also commonly employed in clay testing. Specimens may be prepared by hand ramming, by stiff mud laboratory auger machines, by hydraulic or small dry presses and for some purposes it is advantageous to cast clay into a mold. The shrinkage of clay after various heat treatments is usually determined by linear measurements. Sometimes volumeters are used which take a direct reading in volume. These various heat treatments usually present a reasonable picture of the behavior of clay in the process of making ware. Along with shrinkage, a number of tests can be performed, usually on the same samples. These tests present a full picture of what the clay will do under the treatment.

Dry strength is quite often related to plasticity and is also an indication of the amount of handling that clay might take; fired strengths are quite often specifications, especially in the structural clay products industry. Of course, the strength of the fired ware is a point in handling, also. Strengths may be determined either as compressive, tensile, or transverse. In most control testing transverse strength is used, the tensile and compressive strength tests being somewhat more difficult to perform.

Absorptions and porosities may be determined after any treatments. In the case of determination in the dry state, kerosene must be used rather than water because of slaking of the clay. Here again, many specifications are based on these measurements. Cold water absorptions and boiled water absorptions are often determined and quite often it is found advantageous to use a combination of these two. The ratio of the cold water absorption to the boiled water absorption has been termed the saturation coefficient and probably is a measure, at least crudely, of the permeability of the product. It has been found to be of considerable value in making sewer pipe, terra cotta and, surprisingly enough, good ladle brick. Other methods of testing for permeability are rather complicated.

A few ceramic plants are now using kerosene on fired samples in a vacuum and using a conversion factor based on the density of kerosene against water. They can obtain absorption, porosity, apparent specific gravity and bulk specific gravity in less than 15 minutes. After firing tests, bulk gravity, apparent specific gravity, and the true specific gravity may be determined.

Along with the results of these tests, the appearance of the fired samples and dried sample should be considered as helpful data. Any changes in color usually indicate some change in raw materials. Special drying tests to determine the susceptibility of clay to warping and cracking may be used. Usually these are quick drying tests and often under temperature gradients in the test sample. They are rather difficult tests to evaluate, but can be equated to certain types of shrinkage, cracks, etc., for various types of clay.

The firing of samples for control testing is often done in commercial kilns and in plant practice. This is advantageous in that it is usually done under the same firing conditions that will be used at a later time, being also inexpensive and quite often very convenient. It has the disadvantage that firing in the commercial kiln is rather time consuming, certainly more than in a laboratory kiln. In commercial production, the firing of samples is done under variable conditions. Unless close watch is kept, usually by the placing of cones along with the samples, the actual firing conditions cannot be determined.

These tests are those most often used in control testing of clays. Each use of clay determines the type of testing to be done.

One of the most useful tools that is available is differential thermal analysis. This is a method of test which measures endothermic and exothermic reactions which go on in the dissociation of clays and accessory minerals. D.T.A. is a very good test for the identification of the actual clay mineral present and roughly in what amounts.

Chemical analysis is usually a measure in terms of the oxides present, although sometimes materials other than oxides are determined. There is no measure of the way in which the elements are actually combined. Ignition loss in chemical analysis is usually a very helpful measurement, sometimes indicating carbonaceous material in the clay, other times indicating the type of clay mineral present. Chemical analysis brings out the identity of impurities in the oxide form; however, it is a rather tedious and expensive type of analysis. In recent years the alkali content of clay has been determined by the flame photometer and apparently this method of testing for alkalies is now reasonably well accepted. The alkalies are rather difficult to determine by wet chemical analysis.

Spectroscopic analysis is a relatively expensive type of analysis and rather inaccurate quantitatively; the accuracy usually not being guaranteed any closer than plus or minus 25 percent. It is an excellent qualitative tool however, especially where one is interested in trace elements which could not be detected by a normal chemical analysis.

X-ray analysis is utilized to identify minerals in clay after firing and this method is considered accurate for both quantitative and qualitative work. Petrography is of considerable value in testing clays by identification of the minerals present and sometimes in measuring the size of microscopic particles.

Testing weight loss in firing, although not common, may be done continuously or by draw trials. Each test is usually aimed at the establishment of better firing curves in wares. In determining firing curves the thermal expansion, especially in ware requiring glaze fit, is a very good test and shrinkage in firing is also a useful measurement.

Moisture expansion tests are attempts to produce accelerated weathering conditions, this being often of interest to the structural clay products industry. These tests usually include some type of autoclave treatment of a fired body and a method of measuring the amount of rehydration which will occur. Efflorescence tests are also of interest to the structural clay products industry, but to date no standard test has been developed.

The electron microscope has been mentioned as a tool in clay testing. However, this work is in the fundamental stages. There are various types of tests based on the addition of electrolytes to clays and quite often colorimetric tests, such as the contact print method of analysis which consists of using organic indicators pressed against raw clays to indicate the impurities that are present. Various indicators will show the presence of iron, aluminum, titanium, etc., and this method has proved advantageous in many cases. It not only determines the impurities present but quite often shows how these impurities are combined, their degree of dispersion, and particle size.

SOLUBLE SALT DEPOSITS ON CLAY WARES

By Joseph A. Pask *

Soluble salt deposits—normally white, but sometimes greenish or brownish in color—sometimes form on the surface of clay bodies or clay wares either during drying, firing, or in the wall. Such a deposit has no deleterious effect on the physical properties of the ware but does have an undesirable esthetic effect. Because of the latter, the manufacturers of red and buff firing clay wares strive to eliminate it in the finished wall.

These salt deposits can be classified either by their place of formation on the ware surface or by their origin. Thus, by place, they are referred to as Drier White, Kiln White, or Wall White; and according to origin as efflorescence, scum, or inflorescence. Efflorescence and scumming refer to soluble salts deposited on the exposed surfaces of drying ware, unfired or fired, by evaporation of mixing or absorbed water. Efflorescence, specifically, is the formation of salts by solution of materials that were part of the interior of the ware mass; scumming is the formation of deposits wholly or in part by the action of exterior agents such as gases and vapors upon materials of the ware. Inflorescence, a rarely used term, refers to salts that are deposited from a vapor state on the ware in the kiln during the cooling portion of a firing cycle. Such classifications are not always used, and by common usage all such deposits are generally referred to as scumming.

In this paper the discussion will be primarily concerned with the efflorescent type of salt deposit wherein the soluble salts are within the material, or result from reactions within the material, during firing under oxidizing conditions. Scumming and wall white are equally important, and perhaps more extensive, but generally can be more easily controlled. The SO_2 and SO_3 gases causing scumming result from use at certain stages in the firing process of fuels containing sulphur. Wall white can be controlled by good practice in storing brick, use of soluble salt-free mortar, and good construction practice in order to protect the interiors of the walls from water.

Laboratory tests can determine the tendency for a clay body to effloresce. The wick test is described in Appendix 11 of the Tentative Method of Test for Suction and Efflorescence of Brick, A.S.T.M. Designation C67-42T. Brownell (1950) describes a wick test that uses a clay bar with one end tapered, the other immersed in distilled water. As the water migrates through the brick it dissolves soluble salts, carrying them to the evaporating surface at the thin edge of the specimen.

Published material on soluble salts in clays is extensive. A general bibliography as compiled by Brownell (1949) and supplemented by Hammer (1951) is appended. However, no major advances have been reported since 1884, when $BaCO_3$ was first used to control soluble salts. Brownell's work is important in that it provides fundamental information as to the exact composition of the salts and factual data on the salt formation reactions, and offers an excellent presentation of a possible new way of controlling some of the salts. No specific references will be cited in this report. Data on sulphate reactions are largely from the work of Brownell.

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Table 1. Data on salts.

Salt	Solubility, gm/100 ml.			Dissociation temp., ° C	Melting temp., ° C
	0° C	20° C	100° C		
$Al_2(SO_4)_3$	31.3		98.1	770	
$BaSO_4$		.0002	.00039	1,510	1,580
$BaCl_2$					962
$BaCl_2 \cdot 2H_2O$		35.7	58.7	115 (—$2H_2O$)	
$BaCO_3$		.002	.006	1,352	
$CaSO_4$		.298	.162		1,450
$CaCl_2$	59.5		159		772
$CaCO_3$		$.0015^{25}$	$.0019^{75}$	825	
$FeSO_4$				665	
$FeSO_4 \cdot 7H_2O$	32.8		149^{50}	300 (—$7H_2O$)	64
$FeCl_2$		64.4^{10}	105.7		670
$FeCO_3$		$.0067^{25}$		282	
$Fe_2(SO_4)_3$				480	
$FeCl_3$	74.4		535.7		300
K_2SO_4	6.85	12^{25}	24.1		1,076
KCl		34.7	56.7		770
K_2CO_3		112	156		891
$KAl(SO_4)_2 \cdot 12H_2O$		11.4	L	64.5 (—$9H_2O$)	92
$MgSO_4$	26		73.8		1,185
$MgCl_2$		35.3	42.2		708
$MgCO_3$		.0106		373	
Na_2SO_4	4.76		42.7		884
NaCl	35.7		39.1		801
Na_2CO_3	7.1		33.56		851

NATURE OF SOLUBLE SALTS

The soluble salts most commonly deposited on the finished ware have been identified as K_2SO_4, Na_2SO_4, $CaSO_4$, $MgSO_4$, and $KAl(SO_4)_2$, though other salts such as the alkali chlorides, alkali carbonates, and alkaline earth carbonates have been found. The most serious cases of efflorescence are generally caused by alkali sulphates. Furthermore, the salts in the fired product are not necessarily, and in most cases are not, the same as those in the raw clay, indicating that reactions have taken place in firing.

The common greenish color of salt deposits on ware made from California clays is caused by vanadium. Spectrographic analysis of such a salt indicated a preponderance of vanadium and an appreciable amount of sodium as the principal constituents. The chemistry of the soluble vanadium-containing salts has not been worked out; however, the vanadium is likely part of a complex alkali-containing salt.

All soluble salts regardless of the degree of their solubility cause problems, although larger quantities of the less soluble salts are necessary to produce a certain visible amount of efflorescence or scumming. For instance, a low solubility salt such as $CaSO_4$, produces a noticeable deposit at a concentration of 0.7 percent and an appreciable amount at about 2.5 percent. A high solubility salt, as an alkali sulphate, on the other hand, is noticeable at a concentration of 0.2 percent and appreciable at 0.9 percent by weight of dry clay.

Chlorides and carbonates in the efflorescent salt deposit, if they originate within the clay itself, indicate that the firing temperature was rather low. Such salts, however, can be deposited or developed in the cooling portions of the kiln as inflorescence, but they form on the surface only, and after being washed off do not reappear.

The white sulphates, on the other hand, will persist at the usual firing temperatures of a red-firing clay, 1900-2200° F, as expected according to their decomposition temperatures. Reactions, however, can occur between sulphates and other salts of the alkali and alkaline earth metals. Brownell has indicated a preferential sequence of reactivity of the sulphates. This order is K_2SO_4, Na_2SO_4, $BaSO_4$, $CaSO_4$, $MgSO_4$, and $FeSO_4$. Thus, if several oxides of these cations—for example, CaO and MgO—and SO_3 gas were present, $CaSO_4$ would form first until all of the CaO was consumed, and then $MgSO_4$, reactions would occur either in an aqueous solution to a limited extent or as a solid state reaction. But, no reactions would occur in the solid state with the addition of $BaCO_3$ to K_2SO_4 for the purpose of forming $BaSO_4$. If the reaction should go with the addition of water, $BaCO_3$ would reform during firing. $FeSO_4$ does not persist or remain through firing because it is decomposed with the evolution of SO_3 at temperatures below the maturing range. However, $FeSO_4$ may react with alkali and alkaline-earth carbonates to form their sulphates, prior to the decomposition of the $FeSO_4$.

The sulphur in the clay can be in the form of soluble sulphates, insoluble sulphides, and insoluble sulphates. ''Insoluble'' is not quite accurate, as it is applied to salts that actually have a low solubility. Sulphides are the most important source of sulphur in soluble sulphates. Pyrite, the most common, marcasite, and melnikovite are mineral forms of FeS_2. Hydrotroilite ($FeS \cdot H_2O$) and other iron sulphide minerals such as pyrrhotite ($Fe_{11}S_{12}$) also exist. All of these have varying stability toward conditions of atmospheric oxidation with an end product of $FeSO_4$. The $FeSO_4$, being the least stable of the sulphates, reacts easily with other salts to form the more common soluble sulphates. Thermal dissociation of FeS_2 also takes place according to the equation:

$$FeS_2 \rightarrow FeS + S$$

with subsequent oxidation of S to form SO_2 or SO_3 gases. These may react with existing salts or oxides to form sulphates. It is also reported that the sulphide can react directly with alkali compounds to form alkali sulphates. Also, at high temperatures and in the absence of oxygen, molten FeS and certain molten silicates are partially miscible.

Partially dissociated FeS_2, as FeS, may be responsible for soluble salts that appear on a wall some time after construction. In this case oxygen-saturated rain water on percolating through the brick slowly oxidizes the FeS to a soluble sulphate which comes to the surface on drying. Thus, it would be advantageous to attempt to obtain complete oxidation of the sulfide during firing if the firing is not carried close to vitrification.

PREVENTIVES OR REMEDIES

Use of Barium Salts. All of the barium salts have been suggested as beneficial additives for counteracting soluble salt deposits, although $BaCO_3$ is almost universally used for this purpose. The reaction as indicated in the following example

$$MgSO_4 + BaCO_3 \rightarrow BaSO_4 + MgCO_3$$

occurs either in solution or in the solid state. This reaction is possible because the products have a lower energy content, and are more insoluble than the reactants.

However, there are controversies recorded in the literature debating the effectiveness of adding barium compounds. Incomplete reaction has been attributed to variations in the reactivity and purity of the $BaCO_3$, as well as to mixing and distribution. Thus, the practice of adding an excess of barium carbonate from two to even ten times the stoichiometric requirement is common. The amount generally added is in the range of 0.5 percent of the dry weight of the clay body.

A complicating factor that has not previously been fully realized is the formation of new sulphates during the firing process either by the oxidation of sulphides or by formation of sulphates by action of SO_3 contained in flue gases either in the drying or firing periods. In this case a sufficient amount of $BaCO_3$ may not have been added to take care of the additional sulphate. This condition arises from the fact that the commonly used test for determination of the necessary amount of barium salts is based on a reaction of a known amount of $BaCl_2$ solution with the soluble salts present in the clay and does not take into account the soluble sulphides. When the soluble salts are Na_2SO_4 and K_2SO_4 some other method must be used to eliminate them. $BaCO_3$ will not form $BaSO_4$ in preference to the alkali sulphates.

Firing Temperature. It is an observed fact that increasing the firing temperature in the vicinity of the firing range will generally result in a favorable effect of reducing the deposition of soluble salt deposits on the surface of the ware. Two explanations are available for this occurrence.

Increased firing temperatures increase the degree of vitrification which in turn decreases the porosity or absorption of the ware, so that less rain water, or no rain water at all, can percolate through the ware and bring soluble salts to the surface on drying. The limiting absorption value has not been accurately determined, but available experimental data indicate it to be somewhere between 0 percent and 6 percent. Another result of increased firing temperatures is the promotion of reactions within the body which result in the decomposition of the soluble salts and formation of more insoluble compounds.

Although this method is effective it is not used essentially as a control because of its pronounced effect upon the fired color, and upon the physical properties and dimensions of the ware.

Silica Additions. With the presence of soluble alkali sulphates, $BaCO_3$ additions are ineffective. The sulphates may be present in the clay originally or they may form by the reaction of alkali oxides released from the breakdown of alkali-containing compounds with existing sulphates to form Na_2SO_4 or K_2SO_4.

Examination of the chemical analyses of many clays indicated that those free of soluble-salt impurities generally contained an excess of silica. Also, an analysis of the soluble salts resulting on firing these clays indicated no alkali salts. On the other hand, those clays showing considerable efflorescence and scumming did not contain an appreciable amount of excess silica, and on cooling the crust on the final ware contained alkali sulphates.

Actual experimental additions of from 2 to 10 percent of finely ground silica to alkali sulphate-containing or -forming clays reduced the soluble salt deposit on firing because of the formation of an insoluble alkali silicate. Slight reducing conditions, although not necessary, facilitate the formation of a silicate because the Na_2SO_3 is more reactive with SiO_2 than Na_2SO_4.

Other Measures. Additions of Na_2CO_3 and NaCl have caused an increase of efflorescence in drying but not on firing. It is believed that the additive salts have a fluxing effect upon the salts normally present. Additions of CaF_2 have also resulted in a fluxing effect.

Weathering has been suggested as a means of removing soluble salts, but this treatment in certain cases has also been reported to increase the soluble-salt content. The results are undoubtedly dependent upon the nature of the impurities of the clay. If no sulphides are present, weathering should tend to decrease the soluble salts by leaching them from the clay. However, if sulphides are present, weathering may result in partial decomposition of the sulphides. These are then more reactive and probably lead to more active oxidation at a later stage in the life of the ware. Dipping the brick on removal from the kiln into a weak bath of K_2CO_3 is a scheme that has been used successfully in cases where the salt contains vanadium. No salts then appear on the drying surface. The chemistry of this reaction has not been reported but probably involves the formation of insoluble complex alkali-vanadium salts.

Removal of the iron sulphides should act favorably towards reduction of efflorescence. NH_4Cl reacts with FeS_2 to form $FeCl_3$ and H_2S at low enough temperatures (660° to 750° F) so that the sulphur-containing gases are evolved before the sulphate-forming reactions become appreciable. One or 2 percent NH_4Cl dissolved in the pugging water appreciably decreased the soluble salts in a shale.

CONCLUSIONS

The soluble sulphates of K, Na, Ca, Mg, and Fe are generally responsible for efflorescence and scumming. These salts are either present in the clays as mined or may form during the drying and/or firing of the articles by oxidation of the iron sulfides and subsequent reactions with certain salts or by reactions with SO_2 gases in the dryer and kiln. All of these salts and impurities can occur as part of the clays because clays are secondary and sedimentary in their formation.

To avoid efflorescence these salts must be eliminated in some way. The methods employed are: (a) removal of the salts from the clay; (b) formation of less soluble salts by additives; (c) fluxing or reacting the salts with the clay constituents or additives to form insoluble compounds; and (d) formation of very soluble salts.

Under (a) the method used would be some form of leaching, providing weathering action does not attack certain other compounds, such as sulphides, to form soluble salts. Barium salts are added to form insoluble $BaSO_4$ at the expense of Ca and Mg sulphates, under (b). The Na and K sulphates, on the other hand, are not reactive with $BaCO_3$ in the solid state.

Under (c) the most effective method is the addition of silica which reacts with the alkali sulphates and possibly other clay constituents to form complex silicates. However, other compounds can be formed or additions can be made that will result in reactions at the firing temperatures causing vaporization or fluxing.

Slightly soluble salts may possibly be considered to be the most undesirable in that one soaking and percolation of the ware by rain water will not bring them all to the surface. Thus, after cleaning a wall there will be a recurrence of efflorescence on subsequent wetting. Converting a slightly soluble salt to a very soluble one, under (d) on the other hand, may bring all the soluble salts to the surface on drying after the first soaking. Thus, in this case after cleaning a wall there should not be a recurrence of efflorescence.

Scumming can be prevented by control of dryer and kiln atmospheres at certain stages, and wall white by proper engineering of the mortar and proper construction practices.

Brownell's studies offer a better understanding of the reactions that may be taking place within the ware with and without additives. The possibility of a more scientific approach to solutions of efflorescence and scumming problems now exists. Other phase rule reactions may now be looked for, and it is quite probable that under the stimulus of these ideas more work will be done in the near future.

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CLAY PREPARATION AND STIFF-MUD FORMING METHODS

By Clark Sutherland *

CLAY PREPARATION

All ceramic materials must be prepared for use. Clays have properties which can be enhanced or depressed by the manner in which they are prepared. To most advantageously and efficiently prepare a ceramic raw material, the properties of not only the clay, but those desired in the ware into which it is to be converted, must be considered.

Grinding. Grinding is the process of reducing a material from its largest size to its final usable form. Thus viewed, the first reduction in size occurs in the mining process.

Often the most important step in clay preparation is the method of winning the clay. The method or device used in mining must be such that a material of maximum homogeneity is attained. If the material is not constant in its physical and chemical characteristics as received in the plant, a very elaborate system of controls must be instituted to foresee possible deleterious ceramic effects.

The device or method of mining also influences sharply the size range of the material which feeds the first size-reducing unit. If, for instance, as is quite common in open pit mines, the clay has been won by the ripper and bulldozer, it will be seldom that chunks larger than 3 inches in diameter are received, and primary crushing to reduce material of ordinary hardness to the inch or inch-and-a-half particle diameter range will not be necessary. Further, bulldozer mining also produces a large proportion of fines and will greatly decrease the load on the grinding units in the plant.

If other methods are used, such as power shovels, primary crushing is often necessary. In primary crushing, the most common machines are ones which will accept a very large size of feed and reduce it to a size suitable for secondary grinding, say, one inch in diameter. In the ceramic industry, because more and more comparatively fine grinding is always necessary and this is much more difficult, the capacity and the efficiency of the primary crusher are less important than the size range that it will handle. For primary crushing, the most common agencies in clay working plants are single corrugated or smooth rolls, which rotate towards a crushing plate; double rolls, usually corrugated or toothed; and Blake or Dodge type jaw crushers. Gyratory crushers, although highly efficient, are not popular because they produce material of comparatively limited size range. Hammer mills are successfully used in some clay plants. Recent developments in this type of mill have made it possible to reduce certain materials from 48-inch cubes down to 1-inch size or finer, in one operation.

Most heavy clay products manufacturers who desire to blend and grind materials together have facilities for storing clay that has been through the primary crushers. If only one material is to be used, then economy compels that the grinding be completely finished at one time. In some operations, such as common brick manufacture, a single stage of grinding may be enough; if extremely fine grinding is necessary, two or more stages may be employed.

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* Vice President, Robinson Clay Products Co., Akron, Ohio. The author wishes to thank T. E. Nicholson for his critical review and helpful criticism of this paper.

The question of how much grinding is necessary is an extremely important one. Grinding is always a major component of the cost of the finished product, whether or not it is done within the individual consuming plant. Because of the high cost, no one should do more grinding than is absolutely necessary to attain the desired ceramic characteristics of the material. For common brick it is seldom necessary to reduce the maximum size of their processing unit feed below 4-mesh. Heavy clay products in the hollow-ware field, such as sewer pipe, demand a grind within the 4- to 20-mesh size range. Quarry tile, ceramic veneer, etc., which have finished surface need a 24- to 40-mesh size. White-wares, wall tile, etc., are ordinarily made of materials ground to pass 98 percent through a 200-mesh screen, and certain very high strength dense porcelains, etc., are even composed of materials finer than 325-mesh. The grinding component of the cost of ceramic materials delivered to the first processing unit in a plant may vary from 50 cents to as high as $20 a ton.

In recent years, particularly in some types of clay products, finer grinding has become increasingly popular because of the development of certain desirable physical and ceramic characteristics. Intermediate-size grinding and pulverizing are simply steps in the reduction of clays or other ceramic materials to the size or fineness suitable for further treatment, and are continuations of the crushing process. Because, however, the material has already been primary-crushed to less than walnut size, the question of method and the amount of effort required differs markedly from one material to another. Long ago Rittenger developed a basic law of crushing which stated that the work done is in proportion to the area of the new surfaces developed. This may be otherwise expressed by saying that the work done is in proportion to the ratio of the original and final diameters of the particles.

However, while Rittenger's law in general does hold true, the nature of the clay or ceramic material, and the efficiency of the machine, defined as the ratio of the power actually used to the power used in the machine, produces very wide variations in the effort necessary to reduce different materials in size. Corrective factors must be applied in relation to efficiencies of various sizes and designs of units, the rapidity with which material already fine enough is removed from the grinding zone, the differential volume displacement of the materials in the grinding zone, and many other factors of importance.

The most common device for intermediate-size grinding in the clay products industry is the dry-pan. Of the two types of pans, the bottom discharge type predominates over the peripheral discharge type, which is ordinarily only successful on comparatively coarse-mesh materials, for example, 4-mesh. A modified design has recently been developed in which the outside screen plates rest at an angle, thereby utilizing the centrifugal force of the clay in driving the materials through the screen plates. The factors determining the capacity of a dry-pan are the downward force of the mullers, speed (short of spinning the material out of the pan), the grindability of the material, the proper height of material in the pan, and the proper circulating load. The dry-pan is an ancient device. Its design goes back into antiquity, following machines used for crushing by the ancient Romans. Modern dry-pans, with anti-friction bearings and alloy steels. little resemble those of a few years ago. While a common device in the clay industry, the dry-pan has never been popular in other industries.

Occasionally other media are employed. Many brick plants use heavy duty rolls. Some sewer pipe plants use ring-roll mills. Hammer mills have been tried but decline in efficiency rapidly if moderately fine intermediate-size grinding is employed.

If extremely fine grinding is necessary, in the range of 100, 200, or even finer mesh, Raymond type mills are almost universally employed. Wet grinding, not a common method in the ceramic industry, except in casting processes or glaze preparation, is universally accomplished in ball or rod mills.

Feeders for Grinding Mills. A uniform feed to grinding mills is a requisite for efficiency, maximum production, and uniform product. This fact has led to the almost universal acceptance of some type of regulating feeder as a part of the grinding unit. Such feeders are used to regulate the weight or volume of material coming from surge bins to grinding units. As will be brought out later, the proportioning of the mixture, or blending for grinding, is also often regulated by feeders.

Volume feeders in most common use are the apron type, a series of overlapping slats in the form of a conveyor which moves material from the bins to the crusher; belt fedeers, in which the moving surface is a rubber or steel belt; reciprocating plates, which by a differential speed of motion move the material forward; disc feeders, which are now rapidly declining in popularity; and vibrating feeders. Weighing feeders, which move the feed continuously over a belt balanced to give a weighted feed, are also used.

In modern grinding circuits, the amount of feed is controlled so that the amount of load in the mill is such that it operates at maximum efficiency.

In ball mills, a so-called ''electric ear'' will vary the feed so that the noise level of the mill in operation, a common and reliable gauge of load, can be held at any desired point.

In dry-pans, a more direct approach is possible. The feeding mechanism can be made to increase or decrease its output in relation to the amperage load on the motor driving the pan. Most operators, however, prefer to use a constant feed which they adjust to slightly over-feed the pan, and shut the feeder off and turn it back on at predetermined high and low points of the amperage load.

Particle-Size Control in the Grinding Operation. After or during the grinding operation, the material is graded by one of a variety of methods. Screening is a mechanical separation obtained by passing the materials through openings. In classifying or sorting, the particles are separated by differential settling rates in a fluid, which may be in motion or at rest. Water and air are the two most common media. Separating ordinarily means a grading by some difference in physical characteristic such as specific gravity, magnetic attraction, floatability, or particle shape.

In the clay industries, grading is usually confined to closed circuit grinding with screens or air separators which divide the materials into acceptable or non-acceptable fractions and return the non-acceptable portion to the mill for further particle-size reduction.

Screening is accomplished by passing the material over grizzlies, trommels, vibrating screens, or shaking screens. The most common device used in separating the intermediate-size range of dry ground materials or fine ground wet materials is the vibrating screen.

Vibrating screens are a type of size-grading device in which a gyrating, pulsating, or vibrating motion is applied to the screen surface. They originated from an effort on the part of manufacturers of shaking or reciprocating screens to eliminate the "blinding" or clogging of the holes when sticky material of high moisture content is milled.

These new motions partially solved the problem, but did not eliminate it. In recent years, however, electrically heated screens have come into use. The screening surface is heated by passing an electric current through the wires. The heat prevents moisture from forming on the screen surfaces so that fine damp particles will not adhere and build up on the wires to blind the openings.

At one California plant, for example, over $800 per month in labor is being saved by the use of electrically heated screens. As a matter of dust prevention, water is added in the primary grinding and dry-pan operations. Three men were formerly in attendance constantly cleaning screens. Now, they are seldom brushed at all. In the new installation, semi-permanent dust covers are taken off the screens only at 2-week intervals to check the screens for grass-root blinding.

These electrically heated screens are ordinarily vibrated by the standard means adapted by the manufacturer. To the top and bottom of the screen wire are bolted large electrodes, i.e., 4″ x $\frac{1}{4}$″ copper bus bar. The voltage potential is low, from 1$\frac{1}{2}$ to 6 volts. About 6 kva, five cents worth of electrical energy per hour, is used on a 4 x 6 screen. The screen-wire temperature is raised only enough to dissipate the moisture, usually 120 to 140 degrees fahrenheit, because the screen life is thereby shortened. Heating produces an uncanny efficiency in screens. Screening is complete in the top 2 feet of the screen, so that long screens are a waste of material and energy.

No attempt can be made in this paper to cover the many types of screens now manufactured.

Vibrating screens offer the best device for dry sizing down to the 40- or 60-mesh size. For smaller sizes, mechanical air separators of the centrifugal type are used. They operate efficiently to a point where the finished product may well pass 98 percent through 325-mesh.

The selective action of a centrifugal air separator is the result of ascending air currents tending to lift the finer particles against the combined effect of centrifugal force and gravity. They are a very efficient and universally used mechanism in their field.

Blending. Practically every ceramic plant in the United States, aside from the common-brick manufacturers, is faced with the necessity of blending two or more materials in order to attain the desired ceramic characteristics for the body mix. Many mine operators, because of the variation in clay mines, quite often blend at the mine prior to plant blending. Large stock piles are built up of mined material. These stock piles are composed of layers, which stratify the various materials from the mine. When material is extracted from the stock pile, care is taken to cut across all of the strata. The time interval between mining and use also accomplishes an aging process in the clay.

As a means of insurance against disastrous loss because of raw-material variation, and to establish possible needed variations in standard blending procedure in the plant, it is a common practice of the quality-minded clay products manufacturers to test by laboratory control procedures the ceramic characteristics of their raw materials before they are actually processed. In the manufacture of wall tile, for example, the car-load of talc and of clay, even though already mine and mill blended, is held within a warehouse until representative samples of the material can be run through the entire process under standard conditions before the material is released for use. The processing characteristics of burning size, of cleanliness of body, and of glaze fit, are determined as insurance against a disastrous deviation of ceramic materials. For example, a laboratory test may reveal that a material has been received that tends to make a product which, when burned, is slightly under standard size; that is, the material has greater than standard burning shrinkage. If the condition is correctable, the laboratory releases the material with instructions as to the plant deviation from standard procedure so that a correctly sized product may be attained.

The manner in which components of a clay mix are controlled seems to vary equally in clay plants between volumetric and weight batching. For large-scale operations such as heavy clay products manufacture, the weighing of the components in a batch is an expensive procedure, and most manufacturers of this type of ware use volumetric methods. The number of shovels of material, or the number of clamshell buckets, or the relative parts of a batch car, appear to give a satisfactory means of control. Volumetric proportioning is also accomplished by two or more continuous feeders each of which feed different materials at various rates into a common flow line. Of these, the most successful have been apron, belt or vibrating feeders, of which the writer personally prefers belt feeders. Attempts have been made to control the relative components by means of disc feeders, but variations in moisture and in grain size have seemingly offered insurmountable difficulties to the successful use of this device.

The proportions of materials in the clay mix can also be controlled by their various weights, either by actual weighing of the components of a batch, or in continuous processes, by weighing feeders—a previously described apparatus.

The final stage of grinding is quite often reserved until all of the materials in the final clay mix have been added together, and the milling also acts as a blending operation. This type of circuit also serves to coat the surface of the non-plastic particles with the plastic bonding materials.

The benefit received from grinding the plastic and non-plastic ingredients together is a factor which is often overlooked. Several years ago the writer attempted to separately grind the plastic and non-plastic components of a mix for big pipe with the intention of establishing a plant procedure whereby variable amounts of the non-plastic ingredient, in this case nepheline syenite rock ground to 8-mesh, could be added in proportion to the pipe size. By regulating the feed from two surge bins, it was hoped that pipe could be run on successive days of, for example, 15- and 42-inch size without the necessity of cleaning the bins and changing the mix.

A plant run was made feeding the two streams of clay and rock into an auger machine which pugged the clay for the sewer pipe press. The 24-inch pipe run in this test lacked many of the burned qualities of strength, vitrification, and low absorption normally obtained when the same mix was ground together in the dry-pan. Under the microscope, it was found that the rock particles were not securely bonded by the clay component of the mix.

STIFF-MUD FORMING

General Considerations in the Art of Stiff-Mud Forming. As water is added to a clay in, for example, a mixer or wet-pan, air is gradually expelled from between the particles of solid material. The critical point is reached where the water just fills the pores in the clay, and the material changes from a damp powder to a homogeneous plastic mass. As more water is added, the particles are separated by water film of increasing thickness and the mass becomes more and more plastic until the saturation point occurs. At the critical point, no shrinkage can occur during drying. Beyond it, the loss of increasing thicknesses of water film increases the drying shrinkage.

In the three-phase relationship cited above of air, water, and clay, the importance of completely eliminating the air phase cannot be overemphasized. The presence of any air film between the clay particles instead of water, markedly and adversely affects workability. When the air phase is completely eliminated, the compaction of the clay particles is greater and less water is needed to produce the necessary yield point and elastico-plastic flow of the mixture in response to a given forming pressure.

Stiff-mud forming is the art of producing shapes from water-clay mixtures with a consistency just above the critical point. Considerable force is required to mold or form the clay. Stiff-mud mixes usually contain from 12 percent to 20 percent mechanical water.

Tempering Stiff-Mud Mixtures. The importance of a thorough and even temper of the clay in stiff-mud forming can hardly be overemphasized. For proper tempering, the clay-water mixture must be thoroughly milled until it is a homogeneous mass of the various clay components and water. In modern practice, this is done in either batch or continuous mixers.

The most common batch mixer is the wet-pan or muller mixer. This comprises a revolving circular pan 5 to 10 feet in diameter in which mullers, driven by friction, knead, and in some cases grind, the material until the desired amount of water is uniformly distributed. After the batch is done, the material is lifted out and the process repeated. Wet-pan tempering requires considerable skill. The pugmill is replacing the wet-pan. Being a continuous process, it is easier and requires less labor. When combined with an auger machine it does not, however, do a better job of pugging. The mulling and kneading action in a wet-pan or muller mixer cannot be duplicated by simply passing knives through clay, or even compacting it in a de-aired auger later.

A pugmill is a horizontal hollow trough in the center of which one or more shafts fitted with blades or knives revolve. These knives wedge and masticate the clay and water mixture into a well-mixed mass while it passes through the mill. In modern plants, pugmilling is usually done in the de-airing or clay vacuumizing auger machine. At the end of the pugmill shaft, a sealing auger carries the clay into a vacuum chamber, from which it is forced through an orifice or die by the expressing auger.

Forming Shapes of Stiff-Mud Mixtures in a Single-Stage Process. In stiff-mud forming, the original shape of any article or blank as it comes from the die is formed by pressing. Pressing may be done by intermittent machines or by a continuous extrusion apparatus, depending upon the nature and shape of the desired article.

A press is a device which forces tempered clay to flow intermittently from a clay storage receptacle into or through a die. In the ceramic industry, the term usually means a vertical machine. Irregular shapes, and shapes too large to run horizontally, are formed on presses. A ram press comprises a cylinder which is intermittently loaded with stiff-mud clay, from which the clay is forced by a piston or mud head. The piston may be actuated by a screw or by steam or by oil pressure, driving a ram directly connected to the mud head. In the earliest presses, the piston was screw-driven by manpower. Motor-driven screw presses developed from them. Steam presses grew from our abundance of natural resources in fuel and from the simplicity of design possible with such a machine. Steam is now the most common way to motivate a press. In no place in the world has the steam press been developed to such a high state of perfection as in the United States.

Where exhaust steam cannot be used to advantage, and gas is available for individual heaters, and the ratio of the cost of power to fuel is favorable, hydraulically operated presses of this type have become increasingly popular.

Large sewer pipe, hot tops, flue lining, chimney pipe, and other hollow-wares of large cross-section must be extruded vertically and are ordinarily processed on ram presses. The clay pressure is usually in the 500 to 800 p.s.i. range.

The mud cylinder in modern presses is vacuumized and is usually fed with clay from which the air has been thoroughly evacuated. In such a press clays not ordinarily usable by old-style presses (in which there is a lesser amount of de-airing of the clay) may be successfully processed.

Presses are operated intermittently. The pugging of the clay must be done separately, and is usually performed in auger machines, which in the most modern plants are directly connected to the press.

When shapes are regular in form and are not too large to be extruded horizontally, auger machines are used to force the clay directly through the die without interposing the press between. Labor and investment cost are thus sharply curtailed. Direct and continuous extrusion is possible in not only solid shapes such as brick, but, by suspending core forming devices from spiders, hollow-ware such as partition or wall block, electrical conduit, small flue lining, etc., can be economically and continuously extruded.

Although common outside the United States, intermittent operations on auger machines are a comparative innovation in this country. Auger machines require a large amount of torque and earlier attempts to apply clutches capable of thousands of cycles per day were failures. Now, however, auger presses—mostly horizontal machines—are finding increasing favor.

Closely fitting and well designed augers are capable of exerting much more pressure than most ram presses. The clay pressures, instead of 500 to 800 p.s.i., are in the 1500 to 2000 p.s.i. range. Because of the higher pressures, and the thorough knitting and the de-airing of the clay, a higher modulus of rupture in both the dried and burned state are attained.

In plant practice, auger machines and presses have proved to be much more amenable to mechanization than even a hydraulic press. For those sizes for which auger presses are suitable, the labor and investment cost can usually be reduced by 50 percent or more and the products are of higher quality. At one California company, for example, 8-inch pipe has been processed by both methods under closely controlled and comparable conditions, from a common clay mix and under the same drying and firing procedure. Pipe weighing only 78 pounds, which was processed by auger press, was found to consistently average 25 percent more crushing strength than 90-pound pipe of greater wall thickness formed on a conventional ram-fed de-aired midsection hydraulic press. This effect is attributed to harder temper, better compaction, more air evacuation and lessened lamination.

Influence of Proper Air Evacuation. The writer is firmly of the opinion that a revolution in the heavy clay products industry is impending when the potentialities of high vacuum are better understood by manufacturers. Clays processed at the highest possible vacuum, i.e., $28\frac{3}{4}$ to 29 inches of mercury at sea level, are as much different in their properties from clays processed at moderate vacuum—25 to 26 inches—as moderately vacuumized materials are from materials which are not vacuumized at all. When sewer pipe was processed under a high vacuum, it was found that spider, socket, and spigot cracks disappeared, and drying schedules could be shortened to half the normal period. The blowing of pipe in the kilns, a limiting factor in speed of firing big pipe, was reduced to the point that the firing schedule could also be shortened. When fired, it was found that porosity was decreased and modulus of rupture was sharply increased in the highly vacuumized materials.

Laws of Die Design for Forming Sewer Pipe. In forming sewer pipe on an auger machine, the same basic laws appear to apply to die design on an auger press as apply on a conventional reciprocating ram press for a given clay mix and temper. In considering die design, it must be remembered that different clay mixtures require somewhat different premises.

The following generalizations concerning die design for either process appear to be true for the clays with which the author is familiar:

1. The core supporting spiders, or any other break in flow of the tray transverse to the eventual wall should be corrugated so that the healed line of cleavage is multifolded.
2. Spiders should be roughened to break the alignment of the clay mineral plates along the line of cleavage.

3. The angle of approach of surfaces forcing the clay towards the die should be in the neighborhood of 60° to the line of flow in small sizes of pipe. In large pipe an angle of 30° appears to give better results because of the need for better compaction in thick walls.
4. For the same temper, the length of the slicker surface should be proportional to the wall thickness.
5. For the auger press extrusion, the clay temper can be and generally is harder. For this condition, the angle of approach should be greater and the slicker surface less.

Forming Shapes of Stiff-Mud Mixtures in a Dual Stage Process. Stiff-mud wares are also formed by a dual operation known as repressing. In this process, blanks are extruded, usually on an auger machine, and are cut off to proper size to balance the volume of the article to be formed. The blank is then placed in a mold or die and pressed into the desired shape. Shapes thus formed may be quite complex.

Secondary pressing is widely practiced in the fire brick industry. Norton, in his well-known book on refractories, states that it is estimated that approximately 22 percent of the fire clay refractories are made by the auger and repress. The represses used in this industry are typical of those used in forming tile, quarry tile, terra cotta, etc. They range from simple lever or screw hand-operated machines to toggle or hydraulically powered reciprocating presses capable of exerting pressures of more than 250 tons. Forming pressures of several thousand or more pounds per square inch are becoming common. The mold in which they are repressed may be of steel, cast iron, plaster of paris, or even rubber. Wooden molds are used in the air hammer ramming process for making large shapes in manufacturing refractories.

In repressing articles from blanks, any defects in the homogeneity of the blank or slug must be watched. The repress motion must be such that laminations and the alignment of the clay particles are taken into account. In general, the repressing should be such that the layered materials should be pressed together.

THE DRYING OF CLAY PRODUCTS

By R. K. Hursh *

Plastic clay may be considered as an aggregation of solid particles of very small but variable sizes which are surrounded and separated by water. The surface of the mass is covered with a film of water from which evaporation will take place when it is in contact with air. In order that this evaporation and the process of drying can proceed, the surrounding atmosphere must be capable of taking up additional moisture in the form of vapor; in other words, the air in contact with the wet clay must be unsaturated.

Heat must be supplied and transferred to the wet clay body to accomplish the vaporization of the water. Heat energy is consumed in the evaporation of a small volume of the liquid into a very large volume of vapor. A pound of water will occupy a volume of about one pint. When it is evaporated, the volume occupied by the pound of vapor will be 200 to 300 cubic feet. A large amount of heat is required to furnish the energy for this change. For the process of vaporization alone in the drying of a ton of stiff-mud products, the heat would be equivalent to that produced by the burning of approximately 30 pounds of coal or 375 cubic feet of natural gas or 2½ gallons of fuel oil. This does not include that required for heating the ware, the cars, the air supplied in direct-heated dryers, and the amounts lost from the dryer structure. The heat necessary for the vaporization of the water is, however, the principal item in normal industrial drying of clay products and will amount to about 55 to 75 percent of the total requirement.

When drying begins, the moisture content of the surface layer of the clay body is reduced by evaporation to a value less than that of the interior portions. This establishes a moisture gradient which causes a movement of water from the interior of the mass to the surface through the pores of the material. This flow tends to replace the loss from the surface and to equalize the moisture distribution in the body. The flow of water from the interior will continue as long as evaporation is going on, thereby reducing the moisture content of the entire body.

As water is removed from the body, the volume loss is compensated by shrinkage. The solid particles are pulled closer together as drying proceeds until they are finally in contact and no further shrinkage can take place. The water lost during this part of the drying is termed ''shrinkage water.'' It is nearly equal in volume to the shrinkage of the clay body.

When shrinkage has been completed, there are still spaces between the particles which correspond to the voids in a mass of sand or shot. The water which fills these pores is designated ''pore-water.'' It normally amounts to about half of the original water content of the clay in the plastic condition, 6 to 10 percent of the weight of the clay or 20 to 30 percent of the bulk volume of the body.

As drying continues after shrinkage has terminated, the loss of pore-water is compensated by entry of air into the voids between the clay particles. Some evaporation will then take place within the pores and the vapor diffuses out through the exceedingly small passages to the outer air. In effect, the zone of evaporation is retreating gradually from the surface into the interior of the body.

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Two stages may, therefore, be distinguished in the drying process on the basis of the mechanism of removal of the water and the physical effects of its removal.

(1) Evaporation takes place at the wet surface of the body and shrinkage occurs as water flows through the pores from the interior to the surface.

(2) After shrinkage ends, air enters the pores as drying continues. The evaporation zone gradually retreats from the surface into the body and vapor diffuses out through the pores into the atmosphere.

In the first stage, which might be referred to as the shrinkage period, evaporation takes place from the wet surface of the clay mass in the same way that it would from the surface of a body of water. In fact, this is a period of free liquid evaporation which will continue only so long as the surface is kept wet by the movement of water from the interior of the body at a rate equal to or greater than that of vaporization at the surface.

The rate of drying in this first stage depends on the area of clay surface exposed to the air, and on the drying conditions. Three factors are included in the drying conditions—temperature, moisture content of the air, and the velocity and direction of air movement over the clay surface. These are the controllable factors which may be varied or adjusted to establish a satisfactory set of conditions or a schedule of changes of conditions for the drying of a material or a product.

MOISTURE CAPACITY OF AIR

At a given temperature there is a definite maximum for the amount of vapor which can be present in the atmosphere. This may be expressed as the weight of vapor per unit volume or as the ratio of the weight of vapor to the weight of dry air in the mixture. It may also be evaluated in terms of the pressure which is exerted by the vapor in the air-vapor mixture. Air is said to be saturated when it contains the maximum possible amount of vapor for the existing temperature. Water cannot be evaporated in a saturated atmosphere and drying can take place only when the vapor content of the air is less than that of saturation. When the amount of vapor in the air is less than the maximum—which is usually the case—the air is said to be unsaturated. The condition of the atmosphere with respect to its vapor content is expressed as percentage saturation or as percent relative humidity. The relative humidity is the ratio of the amount of moisture actually present in the air to the maximum amount which could be present in saturated air at the same temperature. Saturation, therefore, represents 100 percent relative humidity. The rate at which evaporation can take place increases as the relative humidity is lowered. It is in direct proportion to the difference between the actual relative humidity and 100 percent. In air at 50 percent relative humidity, drying should be at twice the rate that it would be at 75 percent relative humidity and at two-thirds the rate of 25 percent saturation, provided that the temperature is the same in each case.

The moisture capacity of air depends entirely on its temperature and increases rapidly as the air is heated. In fact, the maximum vapor content of air is doubled when the temperature is raised approximately 20 degrees F. Likewise, the amount of vapor producing a definite degree of relative humidity varies in the same way. The vapor content of air t 100 degrees F. and 50 percent relative humidity is twice that of ir at 80° F. and 50 percent relative humidity, but is only one-half he value for 120 degrees and the same degree of saturation. If the ir is cooled, the relative humidity will increase until the temperature s reached at which the existing moisture content corresponds to the alue for saturated air. Condensation will begin at this point which is ermed the dew-point temperature. This is evidenced by sweating. Cool vare, as it enters a dryer, comes in contact with a very moist, warm tmosphere and the air cools to its dew-point temperature forming a hin coating of moisture on the surface.

Psychrometric Charts. The moisture content of air-vapor mixtures at lifferent relative humidities and in two temperature ranges is shown in igures 1 and 2. The dry bulb temperatures along the horizontal scale are ctual air temperatures. Vertical distances represent the ratio by weight f vapor and air in the mixture in units of pounds of vapor per pound of lry air. This is a convenient method of expressing the moisture content f the atmosphere because the values for a specific mixture are not affected y the volume changes that would result from changes in temperature, s would be the case if the vapor content were expressed as pounds of apor per cubic foot of mixture. This unit is also advantageous in connection with most of the calculations involved in determining quantities o be handled in drying or in air conditioning operations.

The upper curve on the diagram, designated 100 percent relative iumidity, shows the moisture content of saturated air at various temperatures. It will be noted from the vertical scale that the values along his curve are approximately doubled with each 20° F. raise in temperature. Below this are a series of curves indicating moisture content alues for varying degrees of relative humidity in 10 percent intervals. ntermediate values can be readily estimated.

The diagonal lines on the diagram represent constant values of wet ulb temperature. If a thermometer with its bulb covered by a wet cloth r wick is placed in an unsaturated atmosphere, the evaporation of vater from the wick will cool the bulb and the thermometer will indicate a temperature that is lower than the actual or dry bulb temperature of the air. If the wick is kept wet, the thermometer will reach a ninimum temperature reading which will be directly related to the noisture content of the surrounding air, and hence, to its relative iumidity. From the readings of the wet and dry bulb temperatures, he moisture content of the atmosphere can be determined by reference o these charts. A standard instrument incorporating wet and dry bulb hermometers is known as a hygrometer or a psychrometer.

Example 1. The air temperature indicated by a dry bulb thermometer is 70° F. nd the wet bulb temperature is 51° F.

From a point marked 70° on the base line of figure 1, follow the vertical line to a oint midway between the diagonal wet bulb lines marked 50° and 52° respectively. rom here, follow horizontally to the left hand scale and read the value of the moisture content of the air as about 0.0036 lb. of vapor per pound of dry air.

The point representing 70° F. dry bulb and 51° F. wet bulb is between the 20 ercent and 30 percent relative humidity curves and can be estimated as representing 24 percent relative humidity of the air.

Example 2. For 141° F. dry bulb and 129° F. wet bulb, refer to figure 2. The oint on the 141° vertical which lies midway between the 128° and the 130° wet ulb lines is on the 70 percent relative humidity curve and shows a moisture content alue of 0.1045 lb. of vapor per pound of dry air.

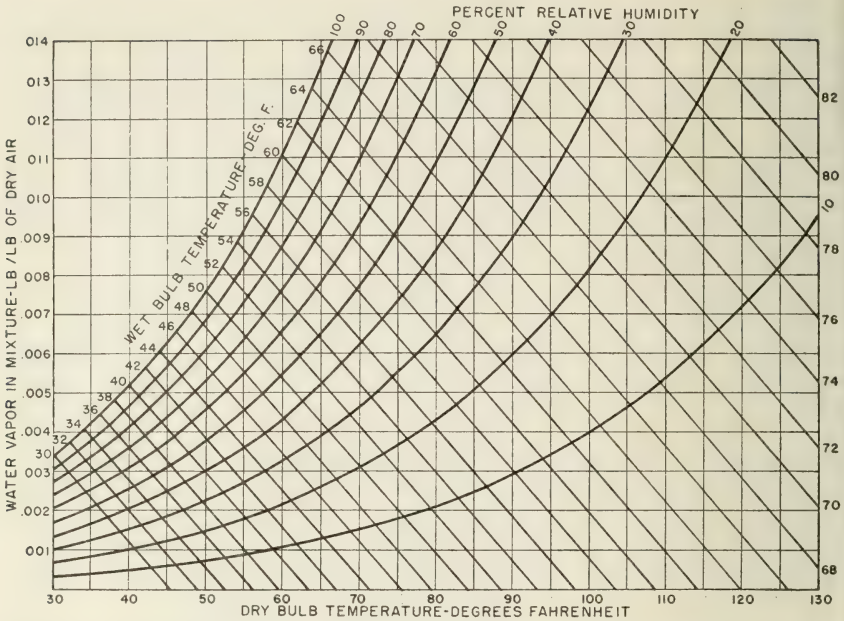

FIGURE 1. Psychrometric chart, 30 to 130 degrees range. Moisture content and relative humidity of air-vapor mixtures for different dry and wet bulb temperatures.

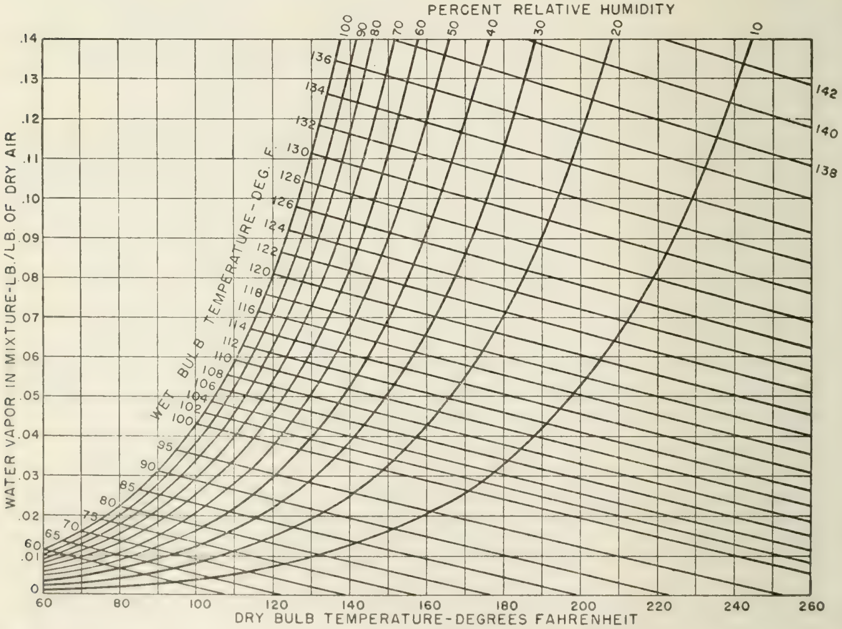

FIGURE 2. Psychrometric chart, 60 to 260 degrees range. Moisture content and relative humidity of air-vapor mixtures for different dry and wet bulb temperatures.

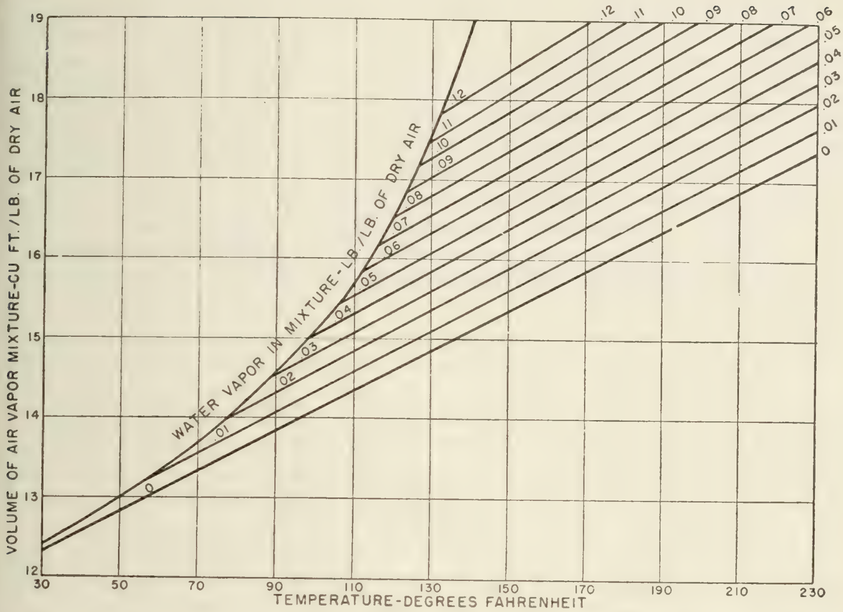

FIGURE 3. Volumes of air-vapor mixtures with different moisture contents; 30 to 230 degrees range.

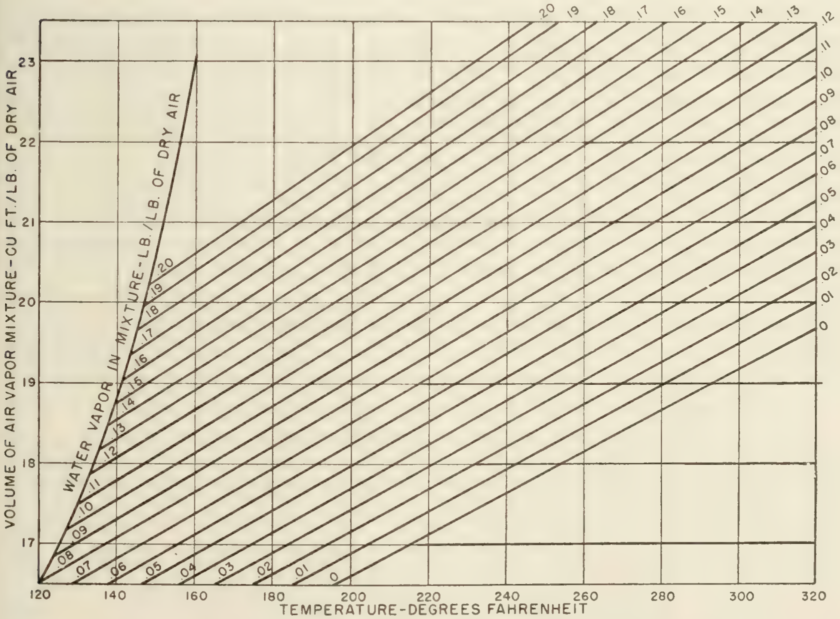

FIGURE 4. Volumes of air-vapor mixtures with different moisture contents; 120 to 320 degrees range.

If an unsaturated air-vapor mixture is cooled without any change in the proportions of moisture and air, as in case of contact with a cold object, the relative humidity will increase until a saturation temperature or dew point is reached. On the chart, such a change of condition would be indicated by the horizontal lines representing constant values of pound vapor per pound of dry air. The intersections of these lines with the 100 percent relative humidity curve shows the dew point temperatures for the various air-vapor mixtures.

Example 2a. From the point indicating the dry bulb temperature of 141° F. and wet bulb 129° F., the path of cooling on the chart of figure 2 would go horizontally to the left to the 100 percent relative humidity curve where the dew point temperature is indicated to be 128° F.

If the vapor content increases and the temperature simultaneously decreases as a result of evaporation of water into the air-vapor mixture, the change in condition will be along the line of constant wet bulb temperature. The mixture will become saturated when the actual air temperature, indicated by the dry bulb thermometer, becomes the same as the wet bulb temperature. Under these conditions, in which the heat used in evaporating the water is supplied entirely from the surrounding atmosphere and there are no heat losses, the diagonal lines represent the path of adiabatic evaporation. In drying, the air and ware are generally cooled in this manner and the wet bulb temperature is practically constant. In the initial stages of drying, the temperature of the ware may often be found to be identical with the measured wet bulb temperature of the air.

Volume Charts. The volumes of various air-vapor mixtures at different temperatures are shown in figures 3 and 4. The horizontal scale indicates the true temperature of the mixture. The vertical scale shows the volume of mixture for each pound of dry air which it contains, or the combined volumes of the dry air plus that of the vapor associated with it in the mixture. The curve represents the volumes of saturated air-vapor mixtures.

If an air-vapor mixture is heated or cooled without any change in the proportions of air and vapor, the volume will increase or decrease in proportion to the change in temperature. This behavior is shown by the straight diagonal lines which indicate the specific volumes at various temperatures of mixtures having the moisture content values shown along the saturation curve. These charts may be used to determine the volume per pound of dry air of a mixture of known moisture content at any temperature within the ranges covered by the charts.

Example 3. In example 1, the moisture content was found to be 0.0036 pound vapor per pound of dry air. The volume of the mixture can be obtained from the chart in figure 3. Following the 70° temperature line vertically to a point between the diagonals marked 0 and .01 and at 36/100th of the space distance above the 0 line, then horizontally left to the margin, the unit volume is found to be about 13.42 cu. ft. per pound of dry air in the mixture. If this mixture were heated without addition or removal of moisture, its volume would increase along a line approximately parallel to those shown. At 240° F. the volume is found from figure 4 to be 17.75 cu. ft. per pound of dry air. At this temperature, the volume containing 100 pounds of air would be 1775 cu. ft. The weight of dry air in 1000 cu. ft. of mixture would be 1000/17.75 or 56.4 pounds.

In a waste heat dryer, the atmospheric air may be heated by passing it through a cooling kiln before it is delivered to the dryer as hot, dry air. In the heating operation there is no change in the moisture content of the mixture but the volume increases in proportion to the rise in temperature, as shown in example 3. As the air passes through the dryer, the moisture content increases as evaporation from the ware takes place. The air is simultaneously cooled by the evaporative process and it is discharged from the dryer at a fairly high relative humidity and at a temperature somewhat above that of the outside air. If the conditions of the air-vapor mixtures at entrance to and at exit from the dryer are determined, the charts may be used to find the amount of moisture taken up per pound of dry air and the unit volumes at the initial and final conditions. Thus the quantity of water that can be taken up by a definite volume of air delivered to the dryer or the amount of air that would be required for the drying of a certain quantity of ware can be determined.

Example 4. Atmospheric air at 70° F. and 60 percent relative humidity is heated to 250° F. and delivered to a dryer. The exit air is at 110° F. and 60 percent relative humidity. From the charts, the moisture contents of the mixtures are found to be 0.0093 at entrance and 0.0342 at exit. The moisture pick-up per pound of dry air is the difference between these values or 0.0249 pound. For each pound of water evaporated from the ware there will be required 1.0/0.0249 or 40.2 pounds of dry air in the entering and exit mixtures. Reference to the volume charts shows that the entering air at 250° has a unit volume of 18.15 cu. ft. per pound of dry air. The exit mixture with 0.0342 pound vapor per pound of dry air has a unit volume of 15.15 cu. ft. The volumes of entering and exit mixture required for each pound of water evaporated from the ware are 40.2 × 18.15 or 730 cu. ft. at entrance and 40.2 × 15.15 or 609 cu. ft. at exit.

The examples are given to illustrate the application of charts of this type for determining the quantities of air needed for drying operations. They serve a useful purpose both in the design of drying equipment and in checking the conditions and effectiveness of operating dryers.

Effects of Temperature on Drying. Temperature is a factor in drying in other respects than in its effect on the moisture capacity of the air. The tendency of the water itself to vaporize increases with its temperature. Hence, in an atmosphere of a definite moisture content, the rate of evaporation will increase with rise in temperature of the ware and of the water which it contains. Also, the movement of water through the pores of the ware from the interior to the surface is facilitated by rise in body temperatures. This is due to the increase in fluidity of water as it is heated. Practical application of this factor is made in some drying operations by an initial heating of the ware in a nearly saturated atmosphere to permit a faster evaporative rate when drying is actually begun.

The rate of transfer of heat to the ware depends on the difference in its temperature and that of the air. The more the air temperature exceeds that of the body, the faster heat is supplied for vaporization and the faster the rate of drying. This applies, of course, only when air is the medium of carrying heat for the drying operation. It is important in heat transfer, however, even in dryers where radiant heating is considered to be the major factor.

Effect of Air Velocity. The rate of drying of a wet material is greatly affected by the velocity of the air flow over its surface and also, to some extent, by the direction of air movement with respect to

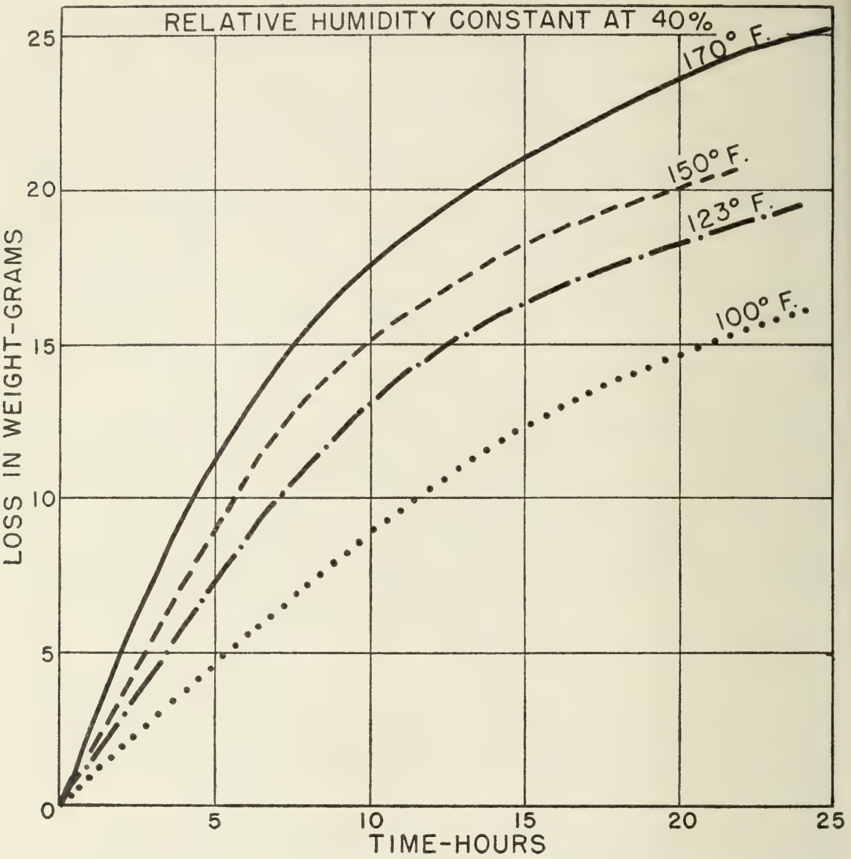

FIGURE 5. Influence of temperature in drying of clay bars under constant atmospheric conditions.

the surface. The amount of water evaporated per unit of time increases in direct proportion to the velocity of the air. In comparison with the rate of drying in still air, evaporation would be twice as rapid if the air velocity were about 250 feet per minute. At 500 feet per minute the evaporative rate would be nearly three times as great as in still air conditions. The effect of air movement is twofold. The rate of heat transfer from warm air to a cooler surface increases as the air movement becomes more rapid and this causes faster evaporation. Also, the air flow removes the vapor as fast as it is formed and thus an atmosphere of low humidity is maintained in contact with the wet material, thus facilitating the evaporative process.

RESULTS OF DRYING TESTS

The influence of the temperature of the air on the drying of plastic clay materials is shown by comparison of curves in figure 5. These show the progressive loss of weight of the material when the atmospheric conditions were kept the same throughout the experiment. In

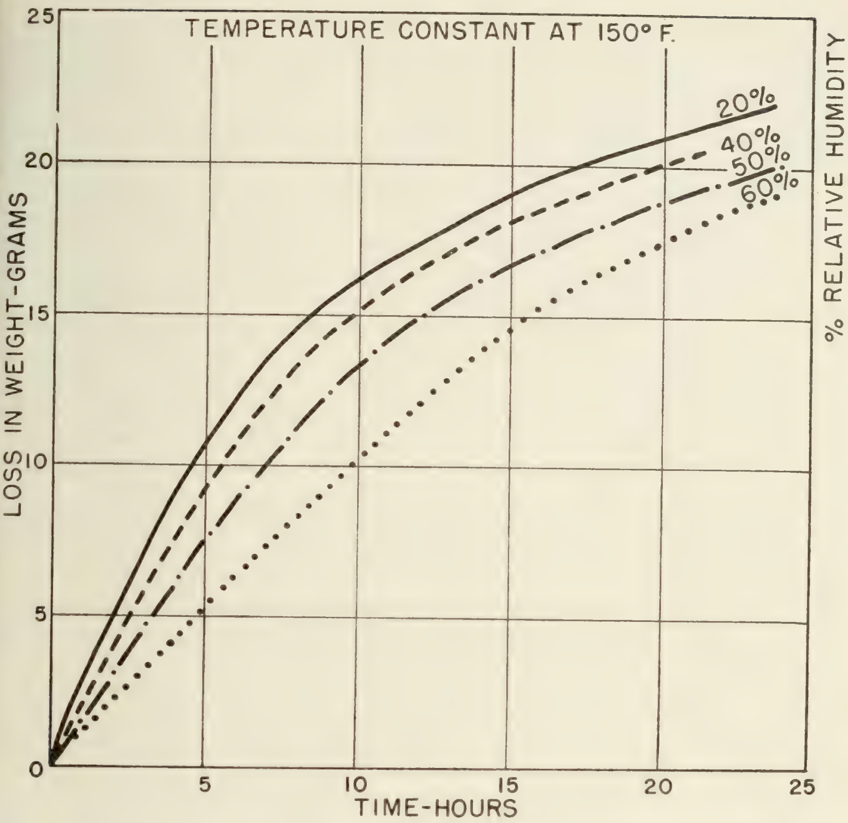

FIGURE 6. Influence of relative humidity in drying clay bars under constant atmospheric conditions.

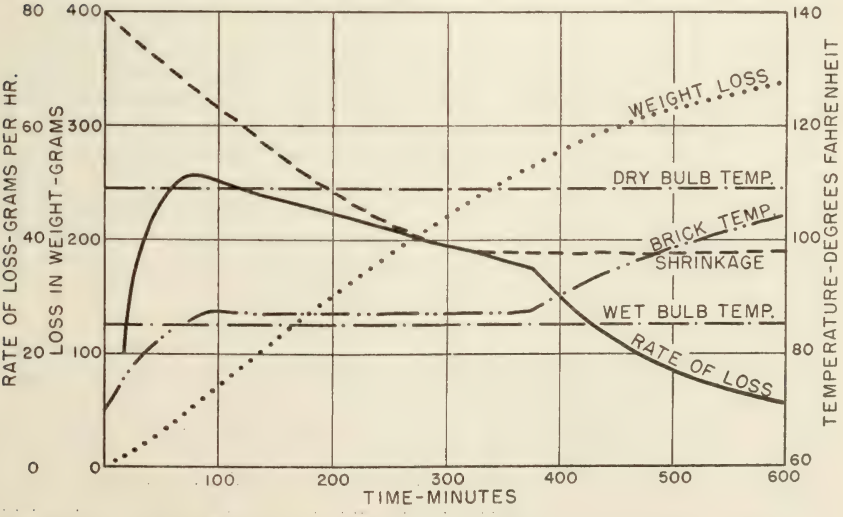

FIGURE 7. Drying of brick with continuously maintained atmospheric conditions, 109° fahrenheit and 39 percent relative humidity.

each case the relative humidity was 40 percent and the rate of air movement was the same in all tests. The amount of water evaporated in a definite period of time is markedly increased with higher air temperature and the time to complete drying would be much less at the higher than at the lower temperatures.

In figure 6 the influence of the relative humidity of the atmosphere is shown by similar curves for progressive loss of weight of stiff-mud specimens. The temperature and air velocity were the same throughout each of the four tests. The time required to evaporate a definite amount of water increases as the relative humidity is raised. In the first part of the drying operation, or during the removal of approximately the first half of the water, the comparative rates of drying or the time necessary to remove a definite amount of water is approximately in proportion to 100 minus the percent relative humidity.

The characteristics of drying clay are illustrated in figure 7 which represents the drying of a stiff-mud brick with continuously maintained atmospheric conditions of 109° F. dry bulb and 85° F. wet bulb temperature. The drying conditions at this low air temperature and a relative humidity of 39 percent may be considered moderate. The smooth curve representing the cumulative loss in weight of the brick does not indicate any change in the nature of the drying procedure except that there is a slight initial lag while the brick is warming up in the dryer. However, when the rate of drying is determined by weight losses in successive short time periods, there is evidence of a distinct change in the process where the straight line for weight loss changes abruptly at 375 minutes. This marks usual division between the first and second stages of drying. Actually, there are three periods indicated by the rate curve.

(1) There is an initial period of warming up during which the brick temperature rises to the wet bulb temperature of the air. The rate of weight loss increases to a maximum as the brick heats up in accordance with the effects of temperature in increasing the evaporative rate.

(2) The second stage begins when the brick reaches or slightly exceeds the wet bulb temperature and the evaporation rate is at the highest value. In the succeeding time interval up to 375 minutes the rate of loss decreases linearly with time due primarily to the reduction of area of evaporation surface as shrinkage takes place. The end of this stage is marked by the break in the curve for rate of weight loss, by the completion of shrinkage, and by a rise in brick temperature above the wet bulb temperature of the air. This is the termination of the stage of free liquid evaporation from a completely wetted clay surface during which the rate of water loss has been controlled by the atmospheric conditions.

(3) In the final stage, generally termed the ''falling rate period'', the surface of the clay article begins to dry off and air starts to enter the pores of the body to compensate for the further water loss. In effect, the zone of evaporation tends to retreat from the surface back into the interior of the clay mass. The rate at which drying can proceed in this stage is determined largely by the nature of the pore system in the clay body and the resistance to the movement of water and vapor through the fine capillary passages. The temperature of the clay is

also an important factor since the fluidity is increased with increase of temperature and the water moves more easily through the pores from the interior to the zone of vaporization. The relative humidity of the air has little effect in this period and the rate of air flow is of less importance than in the earlier part of the drying. Since no further shrinkage takes place, there is little or no development of stress in the body in this final stage and the rate of water loss may be safely increased to shorten the time required to complete the drying.

It should be noted that only under comparatively slow drying conditions does the termination of free liquid evaporation coincide with the completion of shrinkage. When drying is started with a rapid rate of evaporation, due to high temperature or low humidity of the atmosphere, the surface layers of the body tend to dry much faster than does the interior, since the rate of movement of water to the surface is limited by the resistance of the small channels through which it must flow. The outer portion of the body tends to shrink in proportion to its water loss while very little shrinkage can take place in the interior. This causes shrinkage stresses to develop with the outer layer in tension while the middle of the body is in compression. Whenever the tensile stress at the surface exceeds the strength of the clay material, cracks will start at the surface and will extend back into the interior gradually as drying continues. If the outer portion becomes sufficiently rigid in the early part of the drying, there may be a development of internal cracks or fissures when the middle part continues to dry and to shrink away from the outside layer. It is also possible that unrelieved stresses developed during drying may be the source of cracks that appear during the firing process.

In some fine-grained clays the drying out of the surface layer tends to close the pores to such an extent that the movement of moisture from the interior is greatly restricted. The formation of such a dense and relatively impervious outer skin is called "case hardening." It is especially evident in the drying of some highly colloidal substances such as soap or glue.

An example of drying procedure in which the stage of free liquid evaporation ends before shrinkage is completed is shown in figure 8. The initial rate of evaporation is so high that the surface begins to dry off and the break in the curve for the rate of loss occurs considerably earlier than the end of shrinkage. Some cracking of the brick was caused by the stresses developed by rapid drying in the early stages. The shrinkage period is the critical part of the drying of clay wares and the rate of evaporation should be so limited that shrinkage can be completed without developing large differences in moisture concentration in the body.

A slow or moderate rate of drying during the shrinkage period, during which about one-half of the total water is removed, may be followed by an increase in temperature to speed up the water loss in the final stage. The effect of increase in temperature in the last stage of drying is shown by the data in figure 9. In this case a brick was dried in air at 114° F. and 70 percent relative humidity until shrinkage had been completed at the end of 350 minutes. At this point the beginning of the final stage and the more rapidly decreasing evaporation rate is indicated by the sharp change in the curve for rate of loss and by the

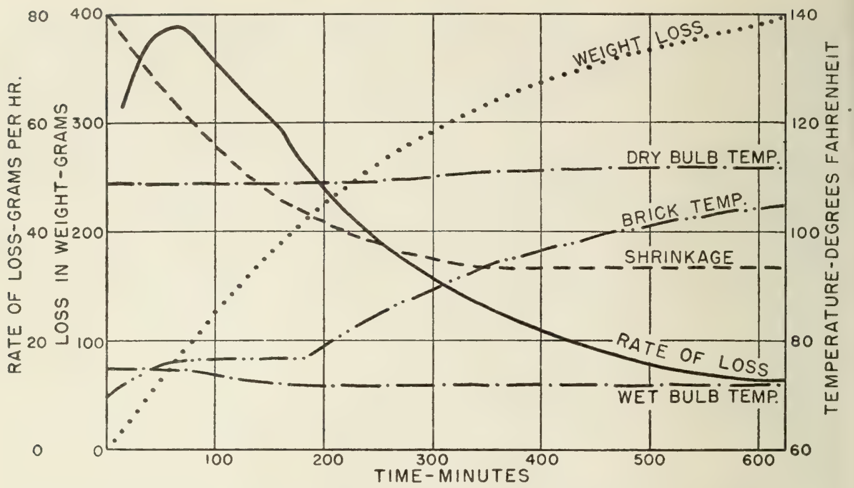

FIGURE 8. Rapid drying of brick with continuously maintained atmospheric conditions.

beginning of a temperature rise in the brick. With the dangers of the shrinkage period past, the drying was accelerated by a rapid increase in air temperature after 420 minutes of drying. The rate of loss curve shows the effect of the resultant rise in temperature of the brick which increased the flow of water through the pores from the interior to the zone of vaporization. By this faster rate of evaporation the amount of water removed at the end of 800 minutes was about 25 percent greater than would have been obtained without the rise in air temperature.

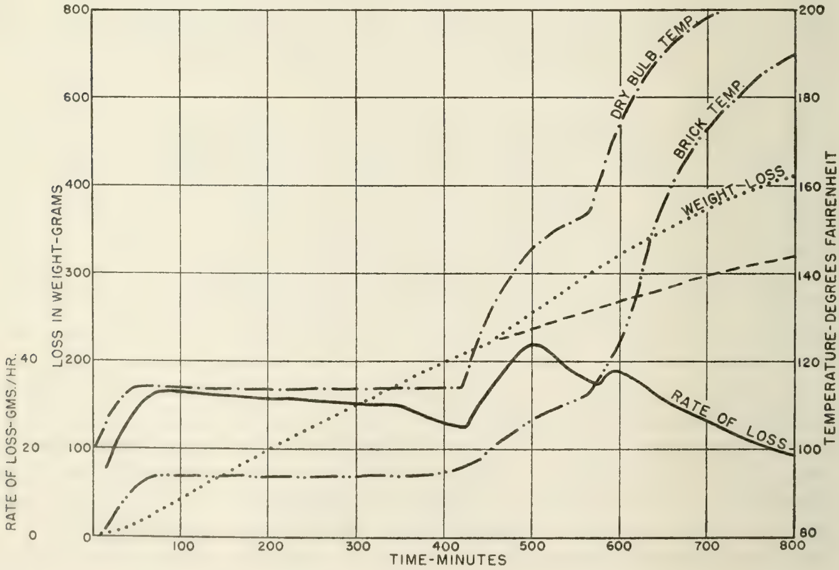

FIGURE 9. Effect of increasing temperature after completion of shrinkage in drying brick.

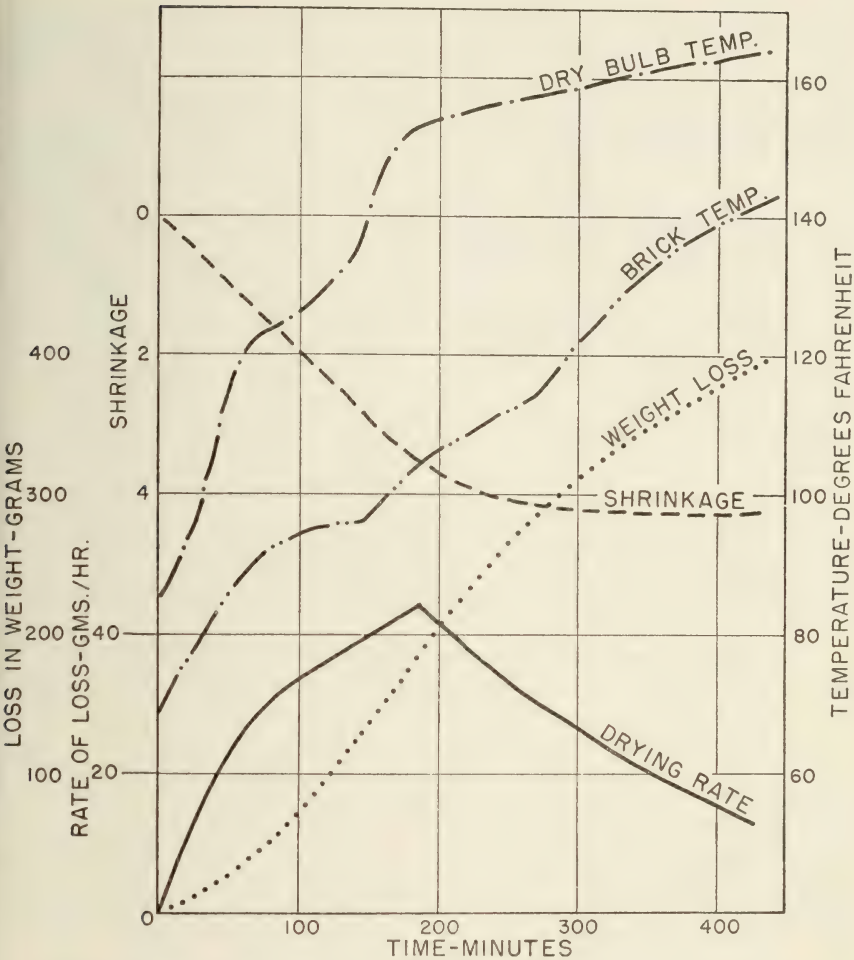

FIGURE 10. Drying of brick with progressively increasing air temperature.

This is shown by comparison of the actual weight loss curve with the dotted extension which indicates what the drying would have been if the original drying conditions had been maintained throughout the time covered by the test. The practical significance of increasing air temperatures in the final stages of drying as a means of shortening the total drying time safely is evident from these results.

It is not normal practice to maintain constant atmospheric conditions throughout the shrinkage period in the drying of brick and similar products. If the clay material does not offer unusual drying difficulties, it is practicable to increase the evaporative rate during the shrinkage stage by progressive increase in the temperature or by reducing the relative humidity or by both methods. By starting the drying slowly in air at relatively low temperature, evaporation can be increased rather rapidly without damage to the brick. The gradual increase in air temperature permits a much higher maximum drying rate than could be safely maintained in the early stage. The time required

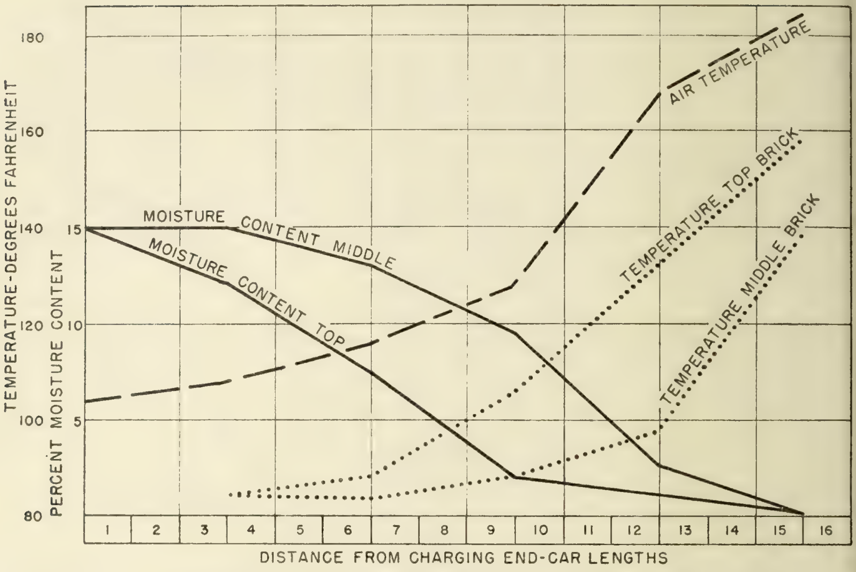

FIGURE 11. Temperature conditions and moisture content of brick in different positions in a progressive tunnel dryer.

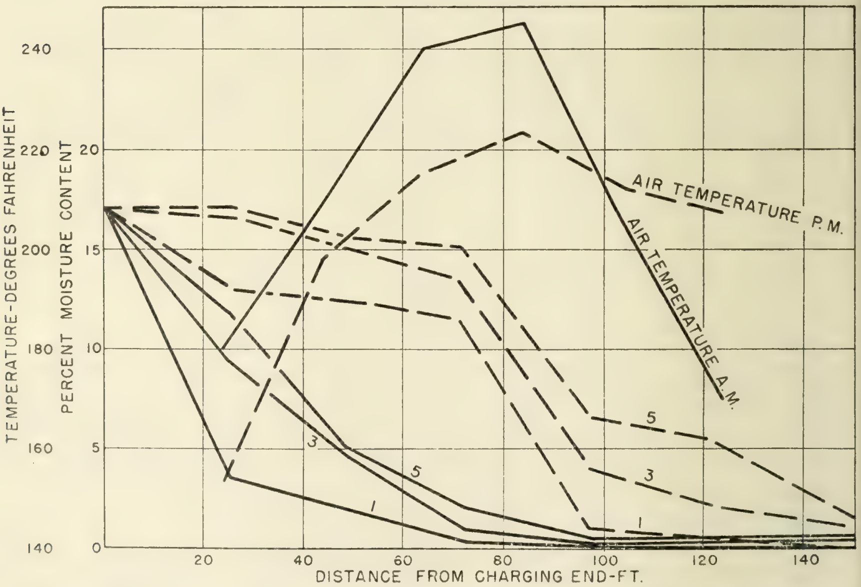

FIGURE 12. Operating conditions in a progressive tunnel dryer with uncovered hot air duct.

to complete shrinkage and the total drying time are considerably reduced by this treatment. In many instances it is found that a slow initial drying rate has the effect of conditioning the clay ware so that a fairly rapid increase in evaporative rate can be used safely and drying can be completed in a minimum length of time. Essentially this is the type of treatment which is obtained in the usual progressive tunnel dryers.

The conditions in a progressive tunnel dryer are shown in figure 11. A progressive increase in the temperature of the air in contact with the brick is shown as the cars move through the dryer. The temperature of the brick does not increase appreciably until a considerable amount of drying has taken place. During the shrinkage stage the clay remains at or close to the wet bulb temperature of the air. A marked difference in the progress of drying in different parts of the car setting is evident from the moisture content and the temperature of brick in the middle and in the top of the cars. In fact, the lower portion of the setting does not begin to dry rapidly until the cars have advanced to a position over the hot air inlets. The rising air provides circulation to maintain evaporative conditions here while the sluggish air movement through the ware nearer the charging end of the tunnel permits it to become saturated, or nearly so. From a practical viewpoint, the regulation of air movement is one of the most important factors in the operation of such industrial dryers.

Somewhat similar conditions are shown for another tunnel dryer in figure 12. The moisture content of the brick in the first, third, and fifth course from the top of the car is shown at various positions along the tunnel. The solid lines show the condition of the ware after it has remained overnight in the dryer without car movement. The dash lines show the conditions in the afternoon after the normal number of cars has been withdrawn from the tunnel. High air temperatures and rapid drying about midway in the tunnel result from the manner in which the air was delivered to the dryer. The hot air inlet duct extended for a distance of 60 feet from the delivery end of the tunnel and was entirely open. This permitted most of the hot air to travel down to the end of the duct before rising through the cars. The wet ware dried very rapidly in this portion of the tunnel but at a much slower rate when it approached the exit end. Improvement of the drying treatment would have been obtained by arranging a covering over the duct with a series of properly proportioned and distributed openings from the hot air duct to deliver the air more uniformly through the cars in the last half of their travel through the dryer.

The data shown in figures 11 and 12 were obtained by arranging openings at several points along a dryer tunnel for measurement of temperatures and for removal of brick from cars for determination of moisture content. Such observations on the operating conditions in a plant dryer can be made without great difficulty. When the position of cars at various time intervals is also noted from the records of car movement, the time-temperature schedule of the drying treatment and the resultant progress of drying of ware in different parts of the setting can be obtained. This affords a dependable basis for modification and for regulation of the dryer operation.

THE FIRING PROCESS

BY R. K. HURSH *

A review of some of the principles involved in the firing process and its effects serves to direct attention to those factors that may influence the quality of the product and the amount of fuel that will be consumed. The characteristics of the clay material should be known and the firing schedule should be adapted accordingly. Standardization and control of the firing procedure can then be established and maintained.

Watersmoking Period. The watersmoking period derives its name from the appearance of white smoke issuing from the kiln in early stages of firing as large amounts of moisture are removed from the ware. This water is gradually vaporized when the ware is heated and is not completely eliminated until the temperature reaches about 550° F. The amount of water to be removed in this stage is generally 1-3 percent but it may be considerably greater if the initial drying of the ware has not been effectually completed.

The water is vaporized within the body and the steam passes out through the pores in the material. If heating is rapid, steam may form faster than it can readily escape and may result in blowing or slabbing of the ware. This is especially noticeable in dense bodies and in products having a laminated structure like that of sewer pipe. With such products, the rate of heating must be slow and ample time should be allowed to complete the watersmoking period safely.

The vapor expelled from the ware must be carried away by air and combustion gases passing through the kiln. The gases are cooled by contact with the ware and by the evaporative process itself. Lowering the temperature increases the vapor content and may result in the gases becoming saturated. Condensation may then take place in the cooler parts of the kiln, especially in the lower parts of the down-draft kiln to such an extent that the ware in this portion of the setting may actually become softened on the surface. When this occurs, the softened clay is likely to deform under the pressure of the ware on top of it. This produces the kiln marking that is sometimes seen in the lower courses of the setting. The absorption of moisture causes the clay to swell as it again approaches the plastic state, and, with subsequent drying, shrinkage takes place. Small cracks or irregular checking of the surface is evidence that the watersmoking procedure has been faulty.

The presence of sulfur gases in the kiln atmosphere may result in scumming, especially in sections where the ware has been moistened by condensation or where incompletely dried ware has been set.

Saturation of the kiln gases can be prevented by increasing the volume of air passing through the kiln in this stage or by increasing the temperature of the gases. The moisture capacity of the gases is doubled when the temperature is increased 20° F. Consequently, increase of kiln temperature is desirable if it does not result in too rapid formation of steam within the body and cause spalling.

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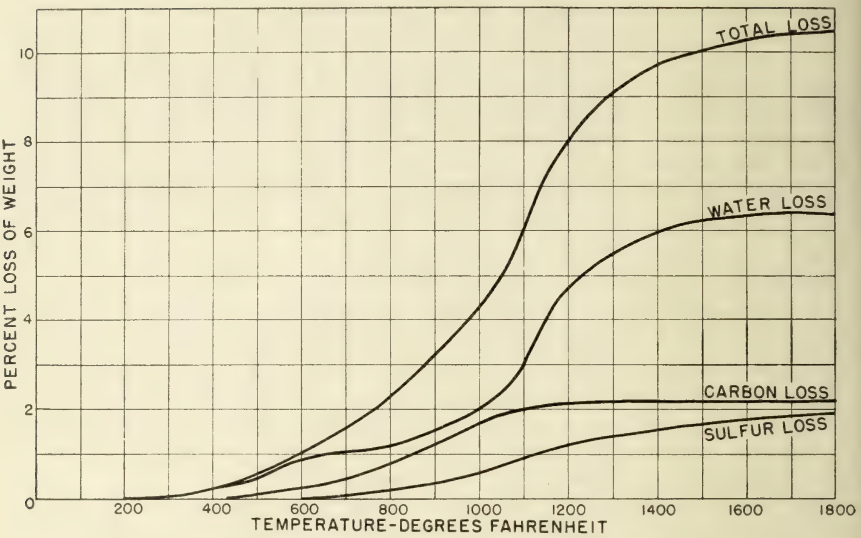

FIGURE 1. Loss of weight in clay during firing.

An enormous quantity of air is required to carry off effectively the several tons of water vapor evolved in the early stages of firing in the ordinary periodic kiln. In the initial stage of firing when starting with a cold ware, kiln structure, flues and stack, draft is negligible and it is difficult or impossible to move enough air through the kiln to avoid condensation. If so, it may be necessary to promote draft and air movement by building a fire in the stack to heat it, or by using a fan in place of or as an aid to stack draft during the watersmoking process. The central stack for a group of kilns is advantageous because it is nearly always hot enough to provide adequate draft for the kiln that is being started. The central stack also insures good draft for later stages of firing.

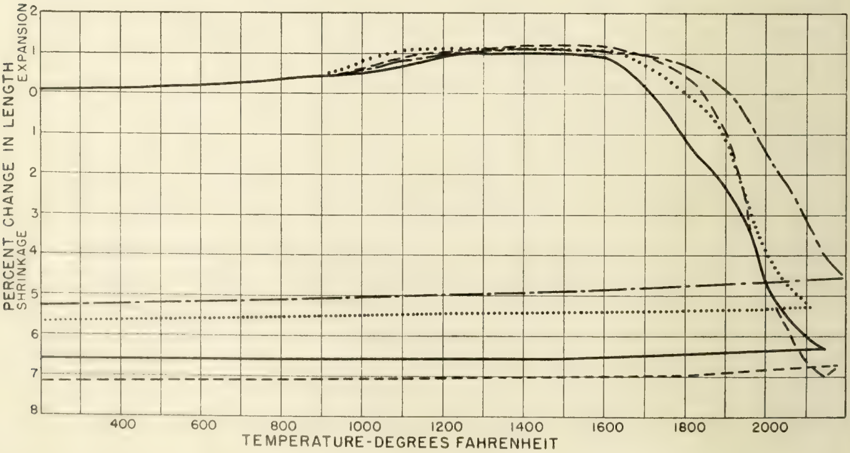

FIGURE 2. Changes in length of clay bodies during firing.

The progress of watersmoking is sometimes followed by suspending a piece of ware in the lower part of a down draft kiln from a balance placed on top of the kiln. By weighing the piece at intervals, the gain or loss of moisture can be detected and the firing conditions can be adjusted accordingly. This is advantageous in a study of firing practice and development of standardized procedures. A thermometer or thermocouple in the slower heating section of a kiln is also desirable as a means of following the progress of heating and watersmoking.

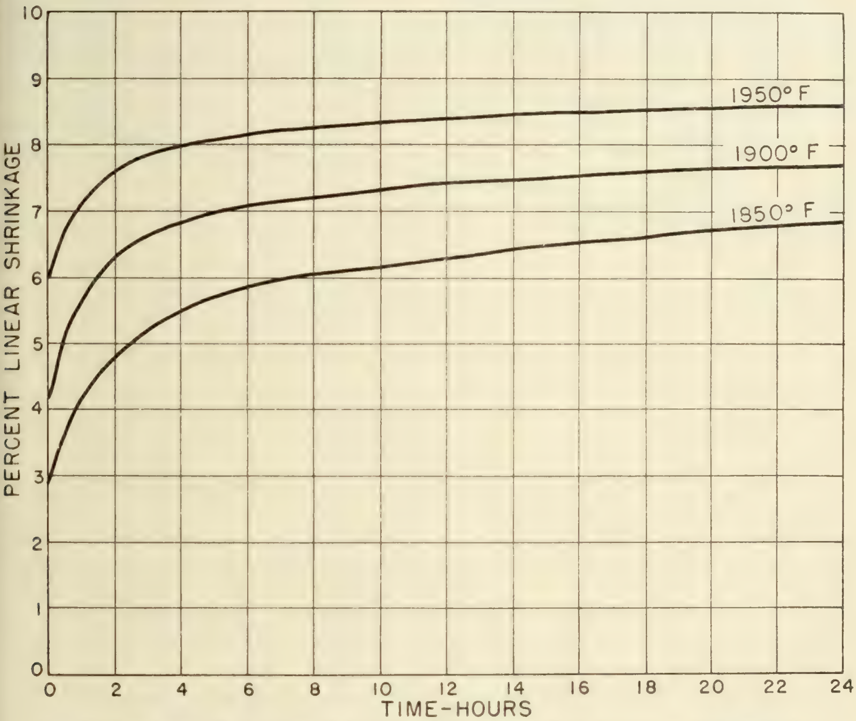

FIGURE 3. Effect of soaking temperature and time on shrinkage of shale H.

Adequate air supply and controlled rates of heating are essential to good firing conditions in this period. In the firing of brick and similar products, heating rates commonly range from 5 to 25° F. per hour, depending on the clay material, the type of product, and its condition when placed in the kiln. In many instances, clay bodies with an open structure permit fast heating rates with little or no danger of damage due to rapid watersmoking. Often there is a tendency to use undue caution and to prolong the watersmoking period with slowly rising temperature or to hold the ware at a constant temperature for long periods. In many cases, considerable time can be saved in firing operations by a well-conducted study of the watersmoking procedure.

Oxidation and Dehydration Period. The oxidation and dehydration period of firing starts at about 600-800° F. and extends up to temperatures of 1600° F. or higher. In this stage of firing, carbonaceous material is burned out of the clay body and some iron compounds are

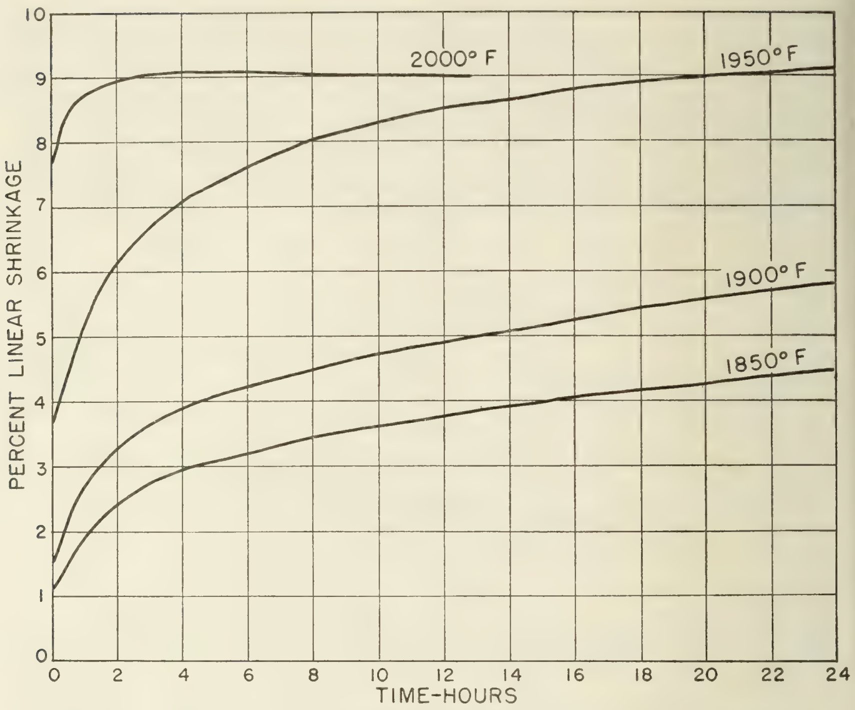

FIGURE 4. Effect of soaking temperature and time on shrinkage of shale A.

decomposed. The iron is oxidized to the minerals that produce red and buff colors in the ordinary clay and shale products. In addition to these effects, the clay mineral itself is decomposed and the chemically combined water passes off. A change also takes place in the free quartz or sandy portion of the clay material which results in a very considerable expansion during the heating and an equal contraction during the cooling at about 1060° F. This may have a very significant effect on the structure of a product which contains much free silica. The changes in quartz particles in the clay may reduce the strength of the ware and give it a punky chracter.

The most important processes in this stage of firing clay materials used for structural clay products, are: the burning out of the carbon and the decomposition and oxidation of the iron sulfide and the iron carbonate. The elimination of the chemically combined water may also have a significant influence since the oxidation process is retarded during the evolution of the combined water from the clay mineral. The presence of sulfur gases from the decomposition of pyrite in the clay, or from the fuel burned, with the water vapor from the dehydration of the clay mineral causes reactions with some of the constituents of the clay. Sulfates are formed which must be subsequently decomposed at higher temperatures in the firing procedure.

Carbonaceous Materials. Some carbonaceous material is found in nearly all clays. It is likely to be present as vegetal material such as plant roots in surface clays. The amount is usually small and this material ignites at quite moderate temperatures. It burns out easily and is not likely to cause any appreciable difficulties in the firing operation.

Bituminous material, such as lignite or coal, is commonly found in many of the clays and shales associated with coal measures in amounts as great as 10 percent or more. Petroleum compounds are also present in appreciable amounts in some shales. Carbonaceous materials of these types are the cause of considerable difficulties in the safe firing of brick and other structural clay products because of their characteristics and the amounts that may be present. Some of these materials are

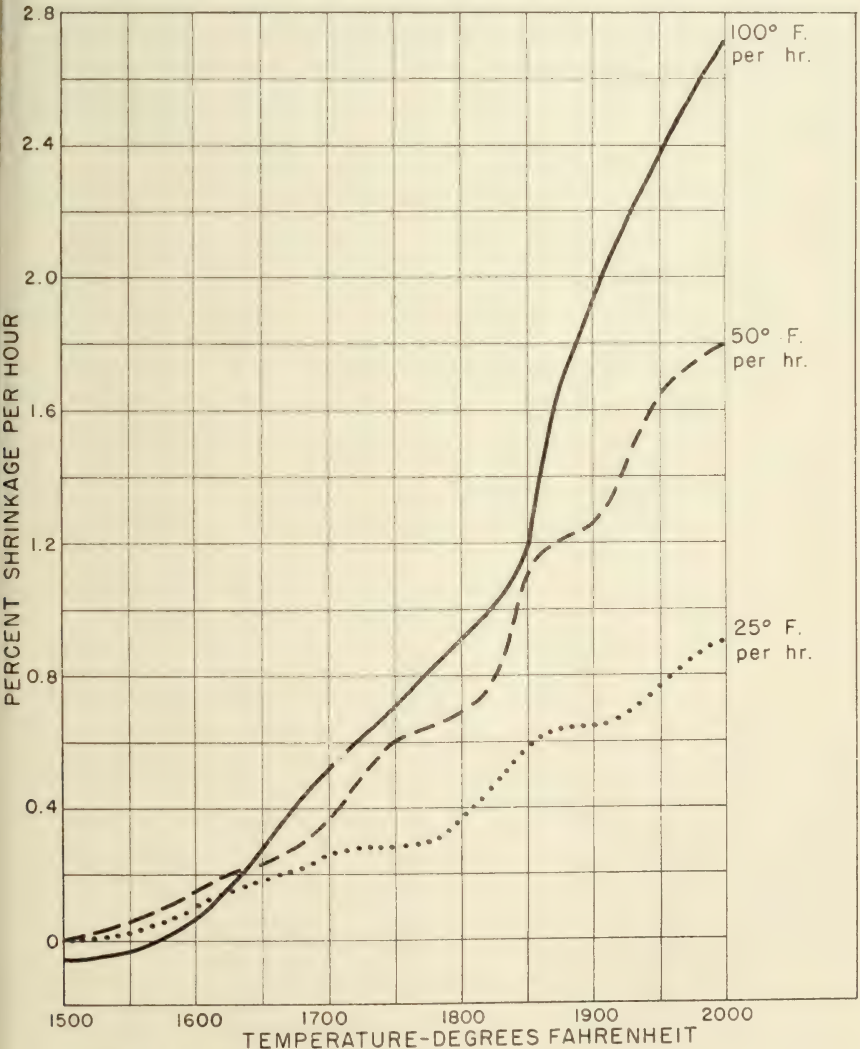

Figure 5. Effect of heating rates on the rate of shrinkage of a shale.

readily decomposed when heated. Combustible gases are given off and a residue of solid carbon may be left in the clay body which is very difficult to burn out.

The combustion of the carbon materials begins very slowly at about 600° F. but it proceeds at an increasing rate as the temperature is raised. If a kiln is over-heated before oxidation is completed, the rapid burning of the carbon is likely to raise the temperature of the ware sufficiently to seal the pores and entrap gases in the interior of the body. The pressure of these gases in the partially softened clay causes the bloating which is the usual evidence of faulty firing in this stage. In less severe cases, the effect can be an area in the middle face of brick which may be either darker or lighter in color than the properly fired portions. There is a stage in the burning out of the oxidizable constituents when the dark color associated with the black core in a red burning clay is changed to a light red or a somewhat buff color before developing the full red color of the normal product. Pyrite pitting in the surfaces of tile that are faced and stacked in the kiln is often associated with incompletely burned out dark cores.

In a down draft kiln in which the top temperatures may have reached 1400° F. or higher, one may sometimes observe rapidly increasing temperature in the lower middle part of the setting as evidenced by red heat developing in this section while the surrounding ware is still black. The combustible material is burning so rapidly in this region that the heat cannot be dissipated fast enough to prevent a rapid temperature rise of the ware. When such local heating occurs, or if it is evidenced by bloated ware in this section of the kiln, the firing rate should be decreased in the range of 800-1200° F. to permit more time for burning out the combustible material at a slower and safer rate. If local heating is observed during the burn, it can be controlled by restricting the air supply and reducing the firing rate. The fire mouth openings should be partially closed to decrease the supply of secondary air and the kiln may be dampered somewhat to decrease the draft and thus decrease the total air supply. The fuel charges should also be reduced sufficiently to slow up the temperature rise of the kiln or to hold the temperature constant for a period. By reducing the air supply, especially the secondary air which enters above the fuel bed in coal firing or through the air inlet openings adjacent to gas or oil burners, the amount of available oxygen in the kiln is so diminished that the burning of the carbon in the clay will be kept at a safe rate. In some plants it is the practice to stop firing when the top temperature of the kiln reaches about 1400° F. or a moderate red heat. The fire box openings are then sealed, the damper is lowered, and the kiln is allowed to stand for a period of about 24 hours. During this period enough oxygen enters the kiln by leakage to continue the oxidation of the carbon in the clay at a safe rate. Normal firing is then resumed. Generally, however, adequate control is obtainable by regulation of the air supply and fuel consumption. The tendency for bloating to develop is much reduced if the kiln is not permitted to get much above 1200° F. before oxidation is well along toward completion.

The progress of oxidation may be observed from the appearance of draw trials taken from the kiln at intervals during this period of firing.

A dark or black center portion in the broken specimen indicates incomplete oxidation. The size of the black core decreases gradually with time until it disappears entirely. The rate at which the core is reduced is much faster with coarse grained or open burning clays than in the case of fine grained clays which become dense and impermeable at low temperatures. The rate of elimination of the black core also increases as the temperature is raised provided the body remains porous enough to permit air to enter and the gases to escape freely. In general, the temperature at which the oxidation can be safely carried out is low for bodies which mature or vitrify at low temperatures and is higher for clays which can be fired to higher temperatures.

It should be noted that the black core in the incompletely oxidized center portion of a clay body does not necessarily indicate the presence of carbonaceous material. Actually the dark color is largly due to iron compounds which have not been oxidized. Some of the iron minerals which are commonly present in red and buff burning clays cause the major difficulties in the oxidation stage of firing of structural clay products. These are the carbonate and the sulfide of iron, siderite and pyrite respectively. The pyrite is the most objectionable.

Iron Compounds. The carbonate of iron may be finely distributed in such clay materials as coal measure shales but it is frequently present in stones of varying size. These stones or concretions may be composed of a mixture of iron and calcium carbonate in varying proportions. The finely divided iron carbonate decomposes readily and changes to the red oxide of iron. The coarse particles which result from the crushing of the concretions in grinding the clays may be the source of pits or craters in the faces of brick or tile.

The pyrite particles vary from microscopic size to large lumps in shales and fire clays. These are decomposed with difficulty in firing and often the sulfur is only partly eliminated when the firing is completed. These sulfide particles are likely to cause pits and pop-outs in the surface of ware during firing or may cause blisters and fused black spots.

The formation of pits, craters, or pop-outs by particles of either siderite or pyrite may occur during firing when insufficient time is allowed for their decomposition in the temperature range of 600 to 1200° F. Prolonged heating with an ample supply of air for oxidation at temperatures of 800 to 1200° F. will generally stop or greatly reduce the defect in floor tile and similar products.

The behavior of the shale or clay body during the oxidation period is shown in figure 1. The progressive loss of weight with a normal heating rate that would be used in industrial firing is shown in the upper curve. The largest part of this loss is generally due to the evolution of steam when the clay mineral decomposes. This begins to be apparent a little above 800° F. and is completed at about 1600° F. Previously there was a smaller loss below 600° F. in the watersmoking stage. The actual loss of water is shown by the next lower curve. The amount of chemically combined water which is lost by the clay during this stage of firing varies from about 5 percent in some of the common shales to as much as 13 percent in some of the purer and more refractory clays. The amount differs with the kind of clay mineral and the amount which is present in the clay.

The portion of the weight loss due to the burning out of carbon in a typical shale or underclay is shown by the third curve. The loss begins about 500° F. and is completed at 1200 to 1300° F. in most cases. The amount of carbon is considerably greater in some materials and the loss of weight due to its combustion would be greater. Some of the carbon dioxide gas that passes off may come from the decomposition of iron and calcium carbonates but the major part represented by these data would be due to the removal of the carbonaceous material.

The evolution of sulfur gases from decomposition of the pyrite, shown by the lowest curve, begins very slowly at about 700° F. and continues at slow rates throughout the remainder of the firing up to or above 1800° F. When any considerable amount of pyrite is present, the elimination is seldom entirely completed in normal industrial firing of brick and similar products made from shales and clays, especially those associated with coal measures. Particles of pyrite which are incompletely dissociated and oxidized during firing are likely to cause pop-outs and pitting after a considerable period of exposure to weathering conditions. This may be observed in many shale face brick in exterior walls of buildings.

While sulfur gas is being formed by decomposition of the pyrite, not all of it escapes in the gases leaving the kiln. The clay itself or some of the iron compounds and other constituents absorb some of the gas to form new sulfur compounds. This absorption of sulfur gas from the kiln atmosphere goes on until the temperature rises above 1100° or 1200° F. At this point or at a somewhat higher temperature these compounds begin to lose the sulfur again while any remaining pyrite continues to decompose. In many cases, sulfur gases continue to pass off from the ware even after firing has been completed. Tests of the air drawn from cooling kilns have shown appreciable amounts of sulfur dioxide to be present until the temperature had fallen below 1500° F.

There is a progressive expansion of the clay body during the first part of the firing treatment. Characteristic dimensional changes of some clays used for structural clay products are shown in figure 2. Up to about 600° F. the increase in length is gradual and is due entirely to the reversible thermal expansion that results from the increase in temperature. A somewhat greater rate of growth may accompany the decomposition of the clay mineral and other chemical reactions involved in the oxidation procedure. When the clay contains a considerable amount of free silica a rapid expansion may occur about 1060° F. due to a change in the crystal structure of this material which takes place rapidly with a large increase in the volume of the silica particle. On cooling, the change is reversed and a corresponding shrinkage takes place at the same temperature. In some cases the volume changes of the quartz particles in the clay during heating and cooling may be sufficient to cause some disruption of the structure or even cracking of the body. A slow rate of temperature change in the region of 1060° F. may be an advisable precaution in both the firing and cooling of clay products when clays of high silica content are used.

At about 1200° F. expansion ceases or proceeds at a negligible rate and the length of the clay specimen remains practically constant while the temperature rises 200-400° F. In this interval the normal increase in length due to rise in temperature is counteracted by sintering effects and possibly by the initial stage of fusion of some of the clay constituents. Shrinkage becomes evident at 1600° F. or lower, indicating the start of the final or vitrification stage of the firing process. It may be noted that settle becomes evident in the industrial brick kiln at this point.

Shrinkage and Vitrification Period. The vitrification of a clay material is due to a process of gradual fusion in which some of the more easily melted constituents begin to soften in the lower temperature range. These gradually react with other portions of the clay to produce an increasing amount of liquid which constitutes the glassy bonding material in the final product.

The fusion procedure is accompanied by shrinkage due to the surface tension of the viscous glass that is formed. The pores and the voids in the body gradually diminish in size and become sealed to produce the final vitrified or non-porous product. The appearance and the physical properties of fired wares are determined to a very great extent by the characteristics and the amount of the glassy phase that is developed during the final stages of the firing procedure. If the fusion process is allowed to proceed too far the body softens and deforms. Bloating will also occur in overfiring due to the release of entrapped or dissolved gases which expand in the sealed or partially sealed pores as heating is continued, producing blebs inside the body and sometimes blisters on the surface.

The rate at which vitrification takes place depends, of course, on the character of the clay body or the amount of easily fused constituents or fluxes that are present. Compounds of calcium, magnesium, the alkalies and iron are the characteristic fluxing agents. These are present in considerable amount in the low-firing clays and shales that are normally used for structural clay products. As the amounts of alumina and silica in the clay composition increase, the fusibility decreases and the maturing temperatures required in firing increase.

The rate of fusion and vitrification becomes faster as the temperature is raised during the final stages of firing. It is necessary to control the rate of heating so that shrinkage does not proceed too rapidly. In the firing of brick and similar products, the progress of shrinkage is commonly followed by settle measurements. It is good practice to control the heating in a typical down-draft kiln setting so that settle does not exceed 2 to 3 inches in a 12-hour period.

The degree of vitrification developed in a ware depends on the duration of heat treatment as well as the temperature attained. This can be controlled by slow rates of heating in the final stage of the burn or by holding the kiln at its final temperature for an extended period of time—both methods giving approximately the same degree of maturity. The slow heating or the soaking treatment in finishing the burn is advantageous because there is less likelihood of overfiring the ware with this procedure. Over most of the firing range, however, there is a practical limit to the amount of shrinkage and reduction of porosity that can be attained at a given temperature, even with extended soaking treatment. This is shown by the curves in figure 3 which represent the shrinkage changes of a shale body during soaking treatments at three different temperatures. The differences in initial shrinkage, at 0 hours, for the respective curves shows the effects of time and temperature

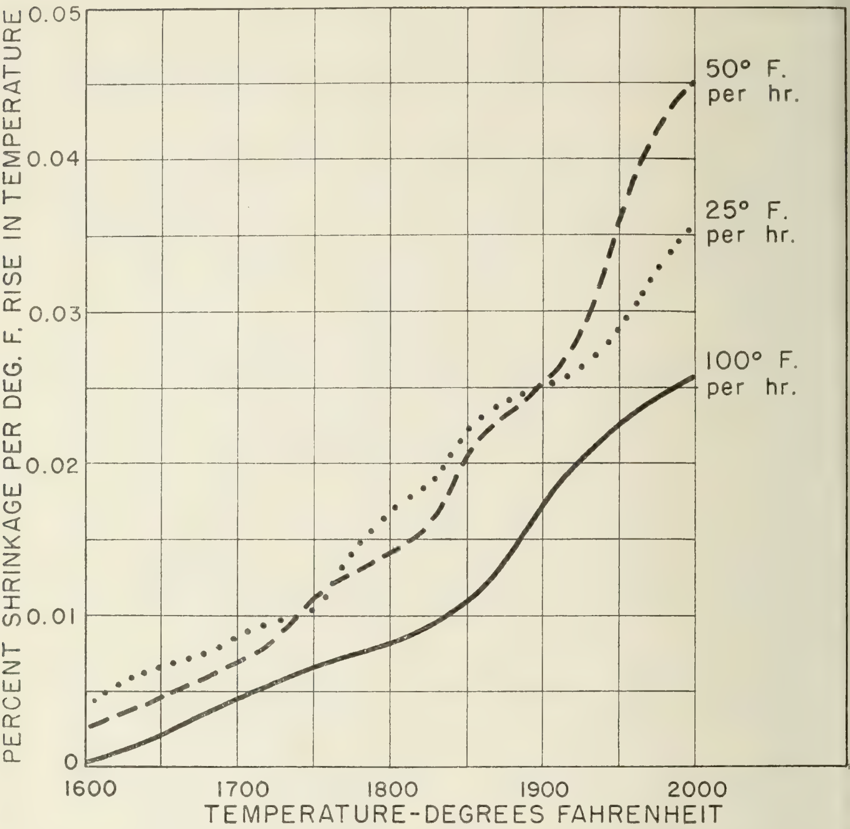

FIGURE 6. Effect of heating rates on the amount of shrinkage per degree fahrenheit rise in temperature.

in heating up to the soaking temperature. The specimens were heated at uniform rates of 100° F. per hour in each case. Vitrification proceeds rapidly during the first few hours in which the clay is held at a constant temperature within the maturing range but at progressively slower rates as time goes on. As much as 80 percent or more of the shrinkage attainable at any specific temperature is reached in the first 4 hours of the soaking treatment. In general, the increase in shrinkage that could be obtained by a much more extended period at a fixed temperature can be effected much more easily by a relatively small increase in temperature. In the case of this shale, a shrinkage of 7 percent was attained after 1 hour at 1950° F. and after about $5\frac{1}{2}$ hours at 1900° F., but this value was not reached even after 24 hours at 1850° F. Similar results are shown by the soaking treatment curves for another shale in figure 4. A large proportion of the shrinkage is obtained in the first few hours of soaking and a small increase in temperature is more effective than prolonged holding at a fixed temperature. With this shale a very great increase in shrinkage results from a temperature rise of 50° F. in the range of 1900-1950° F. as compared with that for an equal rise in other ranges. This indicates a characteristic which is common to many of the clay materials for structural clay products. The marked acceleration of shrinkage rate within a small range of temperature increase is due to rapid fusion of one or more constituents which are present in greater proportion than in some other clays that do not show this characteristic, like the preceding material in figure 3. The increase in the amount of melt may or may not be sufficient to cause complete vitrification in this temperature range. The shale represented in figure 4 could be vitrified at 1950° F. with a sufficiently long soaking treatment, and, apparently, without appreciable danger of overfiring. However, in a kiln in which the temperature wasn't uniform the rapid shrinkage of the ware within this range may easily disrupt the stability of the setting and cause tilting or even falling of the hacks. To offset this tendency, a retarded rate of temperature rise during such periods of rapid vitrification is desirable.

The vitrification of this shale proceeds very rapidly to completion at 2000° F. and the tendency to overfire is indicated by a slight but continuous decrease in shrinkage after 4 hours of heating at this temperature. This is the initial stage in the development of blebs or vesicular structure, the typical effect of heat treatments which are excessive in duration or degree or both. The first evidence of overfiring is always found in a slight change from shrinkage to expansion. Definite bloating follows very rapidly in most cases.

The shrinkage behavior of a clay in firing is influenced to a considerable degree by the rate of heating. The curves in figure 5 show the changes in the time-rate of shrinkage of a typical shale when it is heated at rates of 25, 50 and 100° F. per hour. With slow heating the amount of shrinkage per hour is less than that with faster rates in practically the entire vitrification period. The curves for the 25° and 50° heating rates show a series of intervals of accelerated shrinkage in the approximate temperature ranges of 1650° to 1850°, and 1900° to 1950° F. This behavior is quite typical of the red burning shales

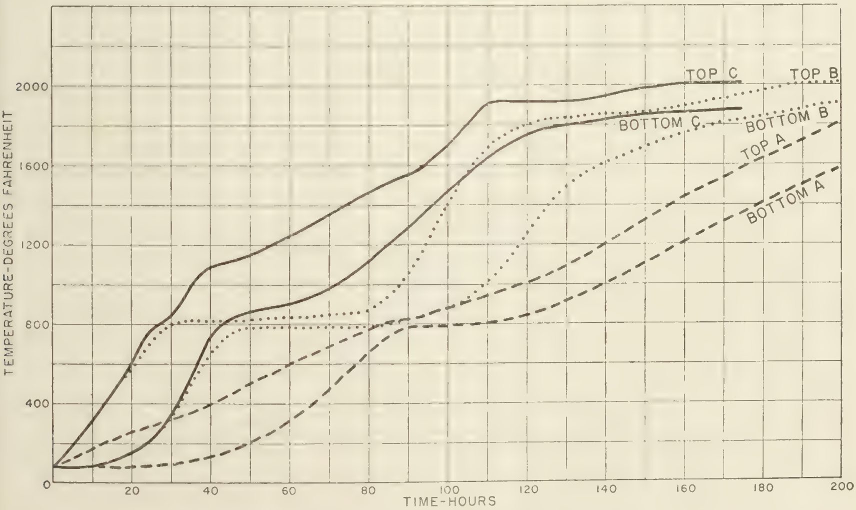

Figure 7. Comparison of heating schedules in firing brick in a down-draft kiln.

and these temperature ranges are fairly representative. The actual amount of shrinkage in a specific range and the comparative amounts for the separate intervals may vary considerably for various shales because of differing contents and proportions of the fluxing materials.

With the 100° heating rate the shrinkage rate is greater and it increases much more rapidly in the temperature range above 1850° F. Because of the rapid heating some of the fluxing processes merge together so that their combined effects produce this result.

The comparative time periods during which ware is in any specific temperature interval are in the ratio of 4 to 2 to 1 for the 25°, 50° and 100° rates, respectively. In order that the same amount of shrinkage might be developed when a specific temperature is reached, the values of the shrinkage rates should be in the same 4 to 2 to 1 ratio. The curves indicate that this is not the case in the lower temperature range. Hence, the amount of shrinkage attained at any particular temperature will decrease as the rate of heating is increased.

Above 1900° F. the shrinkage rate on the 50° schedule increases so rapidly that the total contractions produced in the shale by combined fluxing effects are nearly equal to those for the slower rate. The shrinkage rate with the 100° schedule is still below the proportionate value indicated. Hence, with fast heating rates the ware will have to go to a higher temperature or receive a final soaking treatment to develop vitrification equivalent to that attained with slower heating.

The diminished shrinkage developed in fast heating is evident in comparing the curves of figure 6. The shrinkage produced with each degree of temperature rise is shown for the same heating rates as before. The data used is the same as for figure 5; however, a somewhat different relationship is shown. The importance of time as a factor in the vitrification procedure is well illustrated in these curves. The greater values for shrinkage per degree F. in slow heating are due to the longer time period in a specific temperature interval which is afforded by the slow heating rate. In the final stages of firing, above 1900° F., there is the tendency, previously noted, for the shrinkage effected by intermediate heating rates to more nearly equal those for slow heating. Very fast heating, however, will not produce the same shrinkage as that obtained with slow heating when a specific temperature is reached in any case.

There are definite temperature ranges in which shrinkage of many types of clay materials other than shales is markedly accelerated or retarded during the firing operation. The results given by Van Der Beck and Everhart (1951, pp. 361-365) on clays from central California which are used for structural clay products show shrinkage characteristics very similar to those of the shales. Refractory fire clays, kaolins, and ball clays also show intervals of fast and slow rates of contraction during firing. In the whiteware bodies of various types there are also large variations in shrinkage rate in different temperature ranges during firing.

The effects of rates of heating, temperatures reached and the duration of heat treatment on the shrinkage of clays during firing are especially significant in relation to the control of size of fired products. In order that the shrinkage differences in the ware may be small it is essential that there be minimum variations in the firing treatment in various parts of the kiln setting. A difference of 100° F. in the final temperature may easily cause a variation of as much as a quarter of an inch or more in the lengths of brick. Likewise, the duration of soaking treatments has a considerable effect. Some soaking has been shown to be desirable in order to reach a stage in which the shrinkage rate is low. This will aid in decreasing the size variations in the product. If, as is the general case in industrial down draft kilns, the upper ware reaches an appreciably higher temperature and also has a longer period of time in the maturing range, variations in the size of the fired products are likely to greatly exceed permissible tolerances. The size differences may be and often are as much as ½ to ¾ inch in the length of brick from different parts of the kiln. In tunnel kilns the rates of heating of the ware in top, bottom and center of the car setting are particularly important in respect to shrinkage control.

Atmospheric conditions in the kiln during the finishing stages of the burn have a very great influence on both the color and the size of the product. The effect of reducing conditions in giving dark colors to red burning clays is utilized extensively in producing flashed bricks. The reducing atmospheres are also effective in greatly increasing the rate of shrinkage and vitrification, especially with the red burning clays containing considerable amounts of iron minerals. Over-firing can easily result from such atmospheric conditions in the kiln at the temperatures normally used to mature red brick. It is generally necessary to finish flashed kilns at somewhat lower temperatures to avoid excessive shrinkage and possible bloating. In some instances the effect of a period of strong reduction or a series of flashing treatments at the end of a burn may be equivalent to an increase of as much as 100° F. under oxidizing conditions.

The rate of temperature rise is important in all stages of firing. Slow heating rates may often be desirable to permit safe evolution of moisture during watersmoking, to provide for adequate oxidation treatment before the body becomes dense, and to promote the equalization of temperature in various parts of the kiln. The prolonged firing operation, however, increases materially the labor requirement and, perhaps, the fuel consumption. On the other hand, fast firing rates may cause some defects in the product when the time is not adequate for safe watersmoking and oxidation in all parts of the kiln. Temperature differences throughout the kiln setting also tend to increase with rapid heating, with resultant variations in shrinkage and the degree of maturity of the ware fired.

The temperature conditions in the top and bottom of a down draft kiln for three schedules in firing of brick are shown in figure 7. An unnecessarily slow rate of temperature rise in the top of the kiln in Schedule A results in very slow heating of the bottom and a greatly prolonged watersmoking operation in this section. The mechanically held water in the bottom ware is not entirely eliminated until its temperature reaches 400° F. or higher after 65-70 hours of firing. The low temperature of the gases passing through the kiln would undoubtedly result in condensation in the lower part of the setting for a considerable period of time. This would retard the heating in the bottom and might also cause kiln marking, kiln scumming and checking or cracking of the ware. In this particular operation the watersmoking treatment represented in Schedules B and C was found to be safe and effected a considerable reduction in the time required for the removal of the moisture.

In Schedule B the top temperature was held for 50 hours slightly above 800° F., permitting the upper part of the ware to be oxidized at a very slow and safe rate. This holding period also allowed the bottom ware to heat up so that there was only a small difference in top and bottom temperatures. The temperature in the bottom was not sufficient, however, to effectively oxidize the ware in this portion of the kiln. This resulted in a considerable temperature lag in the bottom when the fast heating of the top began at 80 hours. A better oxidation procedure is indicated in Schedule C, although it is probably not the most effective one that could be developed. A somewhat retarded but a steady rise in top temperature in the range of 800 to 1200° F. or higher will permit the top ware to oxidize at a safe rate. At the same time the bottom ware will more quickly reach effective oxidation temperatures. Its oxidation can be completed earlier and with less temperature lag when the final shrinkage stage is reached than resulted from Schedule B. Consequently there is less temperature difference in the various parts of the kiln when the vitrification period begins and the shrinkage of the ware is likely to proceed more uniformly and with a smaller size variation in the finished product.

A standardized firing procedure should be developed from study of the firing characteristics of the material and the kiln conditions in the firing operation. Information as to the temperature conditions and the rates of heating of the ware in different portions of the setting throughout the firing operation is essential to establishing a standardized procedure in both periodic and in continuous kilns. To get this information and to effectively use it, adequate records of the firing procedure and of the quality of the product should be obtained on each kiln and burn. These should not merely be filed but should be examined and compared regularly as a basis for making desirable changes in operation and also to insure the maintenance of standard procedures.

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TEMPERATURE MEASUREMENT IN KILNS

BY JAMES L. HALL *

During firing it is difficult, if not impossible, to measure the temperature in or close to the ware. Therefore, we must rely on devices other than thermocouples to tell us the story of what is happening or has happened in firing. This discussion is in two sections: the first is a discussion of devices used in measurement and control of firing; the second is a description of the results obtained.

Thermocouples are very important for measuring temperature and are widely used in ceramic kilns. Only two types of thermocouples are employed to any great extent in ceramic firing; namely, chromel-alumel (Cr-Al) and platinum-platinum rhodium (Pt-PtRh). The former has the advantage of being relatively inexpensive. Because it is inexpensive it can be made of heavy-gauge wire and is therefore rugged and can be moved without too much danger of breakage. It also produces a relatively large voltage for a given temperature. Cr-Al has the disadvantage of failing rapidly above 2100° to 2200° F. For higher temperatures the Pt-PtRh couple is used, which yields about one-quarter the voltage of the Cr-Al couple. The dividing line between the use of these two couples is cone 3 to 4.

Tunnel kilns ordinarily have Pt-PtRh couples in the firing zone, and Cr-Al couples in the cooler portions of the heating-up and cooling zones. A double-range instrument or separate instruments are used to convert the voltage to temperature. Periodic kilns firing sewer pipe and chimney pipe ordinarily utilize one Cr-Al couple situated near the center of the crown, while terra-cotta or other batch kilns firing at higher temperatures utilize a Pt-PtRh couple in the crown. An important consideration is the placement of the hot junction of the thermocouple. Because of the conduction of heat away from the hot junction through the thermocouple wires and through the protection tube, the temperature of the hot junction will be somewhat lower than the temperature of the surrounding gases unless the thermocouple is inserted far enough into the kiln to isolate the hot junction from the cooler kiln walls. As a general rule, the hot junction should be inserted a minimum distance of at least four times the diameter of the protection tube; an insertion of six diameters is safer.

PYROMETRIC CONES

Probably the most important single device for determining firing temperatures is the pyrometric cone. This device was invented about 1880 by the German ceramist, Seger, who made up a series of silicate mixtures, each of which melts and flows readily within a characteristic narrow span of temperature. Made up into small pyramids or sharp-pointed cones and set at a slight inclination, these silicate mixtures bend gracefully at fairly definite temperatures until the tip comes down level with the base. Seger's series proved unsatisfactory because at that time the principles of phase equilibrium and the existence of eutectic mixtures in multi-component systems were but imperfectly understood. Since his time, however, the methods of blending and preparing the

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cone materials as well as their formulation have been sufficiently standardized to secure uniform and reproducible results. The complete series now in use comprises 61 cones, from cone 022 to cone 42. Cone 022 deforms at the lowest temperature, about 1100° F. From cone 022 the numbers decrease to cone 01 which deforms at about 2050° F; then comes cone 1 which deforms at about 2100° F; the numbers then increase to cone 42, which comes down at about 3600° F. The average interval between adjacent cones is about 40° F. Cones nos. 21, 22, 24 and 25 are omitted, while no. 32½ has been included. "It must be emphasized that the pyrometric cone is not a true pyrometer, for its bending does not depend upon temperature alone but also upon the time interval during which it has been exposed to a given temperature. It is best not viewed as an individual indicator but always as a member of a series. So successful have pyrometric cones been in the control of the firing process that true pyrometers are used only as an auxiliary tool. One reason is the inexcessibility of the middle of the setting in a fixed kiln or the middle of a car of brick in a tunnel kiln. To use a thermocouple many feet of thermocouple wire would have to be run and a long protection tube used, and the difficulties of placing such a tube in the midst of a setting of sewer pipe, for example, are easily imagined. A thermocouple on a moving car in a tunnel kiln is not very practical for everyday use because of the necessity for electrical contacts. Again for firing terra-cotta or firebrick, the temperature is usually so high that only platinum thermocouples can be used, and platinum couples are expensive. A total radiation pyrometer can be sighted into the setting, but it has a cone of vision of appreciable angle and cannot be sighted on an area of a few square inches at a distance of eight or ten feet, as would be necessary if we were to read the temperature far back among the ware and not be misled by the relatively large effects of nearby surfaces. There remains the optical pyrometer which is capable of measuring accurately the temperature of very small and very distant objects, but it requires always the individual judgment of an observer and makes no automatic or continuous record. The latter is true also, to be sure, of the pyrometric cone, but the cone stays on the job and begins its cycle of reactions when its temperature is reached—whether an observer be on hand or not. Hence from the stage of bending of a group of cones placed in the midst of a setting and observed through a narrow channel between the pieces of ware in a kiln an experienced fireman can make a close estimate of the course of events just preceding his observation" (Sosman, 1938, pp. 37-49). If the cones are set blind the fireman can judge the course of his burn after the kiln has cooled and been drawn, and thus can estimate his accuracy and make adjustments for the firing conditions of the next burn.

Cones are sometimes considered a measure of heat work because of the effect of time and temperature on the deformation behavior. The degree of maturity in a fired ceramic body, within limits, is likewise controlled by such factors. Because of this, cones are said to measure the degree of maturity obtained by the ware under heat treatment. This consideration must, however, be tempered by the exactness of comparison of the degree of maturity. For example, it has been found that glazed terra-cotta will show a considerable range of color when burned to cone 8 in a tunnel kiln with a 4-day heating, firing, and cooling schedule as compared to the same type ware burned in a periodic kiln at cone 8 with a 10-day turn-around period. In another example it was found that ware in a laboratory electric kiln of approximately one cubic foot capacity could be fired to give nearly the same shrinkage and absorption as companion pieces fired in a tunnel kiln, but the laboratory kiln had to be fired two to four cones lower. However, depending on the body mix, the criterion in this case was resistance to crazing in 150 lb. per square inch autoclave test. The pieces from the laboratory kiln failed the test miserably while the pieces from the tunnel kiln showed no crazing. This degression should not be taken to mean, however, that pyrometric cones are not reliable or useful because they are, and very much so. They are extremely valuable in comparing different burns in the same kiln and the comparison only falls off when kiln sizes, fuels, schedules, and other factors become widely divergent.

OTHER TEMPERATURE-INDICATING DEVICES

Other devices for controlling the burning of ware include try pieces which may be drawn from the kiln at desired times and tested to determine the course of the burn. Included here are glazed pieces which are examined for maturity of glaze in terra-cotta kilns. Shrinkage markers are sometimes put on try pieces to determine a course of the burn, and in this instance the appearance of the try piece itself is sometimes a good indication of the maturity of the ware. Veritas rings consist of a small ring or cylinder of definite composition which is placed with the ware and withdrawn at intervals during the burn. The shrinkage of these rings is measured with a simple lever device, and when the shrinkage has reached a predetermined value, the kiln fires are extinguished. Some scove kilns are set with openings down into the setting so that rods may be inserted as the firing progresses. The depth of the rod indicates settling or shrinkage of the brick during the fire, and the fires in different parts of the kiln may be equalized as the need is indicated by the depth of the rod.

Any quality of the ware which is desired in the final product may be used as a delayed temperature or maturity measurement and thus as a control in firing. For example, the absorption specification for sewer pipe is generally 8 percent or less. If it is found that ware is running at or over the 8 percent value we know that we must adjust the burning to lower the absorption. In the same way the appearance or color of some flashed roof tile is the criterion for their acceptance.

No single one of these devices will give the whole picture in firing, and the usual procedure is to use two or more together. For example, in firing sewer pipe in periodic kilns the thermocouple is used during the heating-up and cooling-down portions of the burn to regulate the desired rate of temperature increase or decrease. When the temperature begins to reach the point in the region of bending of the desired cone, the fireman shifts his interest to the cones and regulates his fires by their indication. In firing terra-cotta the thermocouple is used in the same manner to indicate the rate of temperature increase. However, when the cone at which the burn is to be fired starts bending, the temperature of the kiln as indicated by the thermocouple is held without increase until the heat is made to soak down and equalize throughout the kiln as indicated by the cones. The fires are then extinguished and the rate of cooling of the kiln is adjusted by the indications of the thermocouple.

So much for the devices used in depicting the temperature conditions in our kilns. Now what are the actual temperatures as they occur in different types of kilns? In the first place, there is no such thing as a typical temperature in a typical kiln. If taken down to a fine enough point no two kilns are ever the same, and even with two kilns very much alike in dimensions, ware being fired, and other considerations, the temperatures might be found to cover a considerable range. It is sometimes said that we do a good job of firing the thermocouples and only sometimes does it follow with the ware. M. P. Hall has illustrated what this means with his discussion of temperatures in the tunnel kiln (Hall 1952, pp. 85-88).

TUNNEL KILNS

The simplest visualization of a tunnel kiln is that of a long pipe lying on its side. In one end we put the ware, and it is pushed continuously along the length of the pipe. Our purpose is to fire the ware, so we introduce heat at the center of the pipe. The heated air, being lighter than the surrounding air, will rise, and naturally will tend to spread out along the length of the pipe in both directions from the center. We wish to use this hot air for heating up the unfired ware, so we install exhaust ports and a fan near the entrance end of the kiln and draw the air along that portion of the kiln. In the opposite end of the kiln our purpose is to cool the ware, so we introduce cold air at the exit end of the kiln and force the air toward the center so that as the ware cools the air itself is heated. At different points along the length of the kiln we install thermocouples in the crown so that we may know the temperatures at these points. We adjust the fires in the firing section and the draft in the heating up and cooling sections.

By plotting each temperature point as indicated by the thermocouple we will have a curve such as that shown in figure 1. This

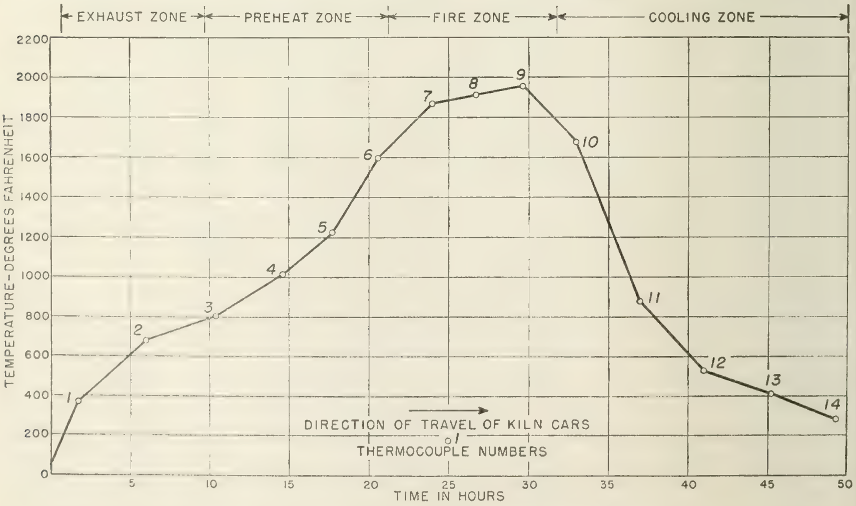

FIGURE 1. Firing curve of a typical tunnel kiln.

appears to be a satisfactory firing curve, but is this the true temperature for the ware going through the tunnel kiln? Is any part of the setting at the same temperature as the crown thermocouples? Is there any difference in the temperature between the top and the bottom of the setting? To find out the answers to these questions travelling thermocouple tests have been run in many tunnel kilns. In the example in figure 2 sewer pipe is being fired. One thermocouple is placed with the hot junction near the top of the setting and a second thermocouple is placed with the junction near the bottom of the setting just above the car deck. The thermocouple wires are brought down through a hole in the car and lead wires are fastened on so that they will run freely under the bottom of the car between the wheels. These lead wires are attached to a recording instrument that will give a continuous record of the top and bottom temperatures as the car progresses through the kiln.

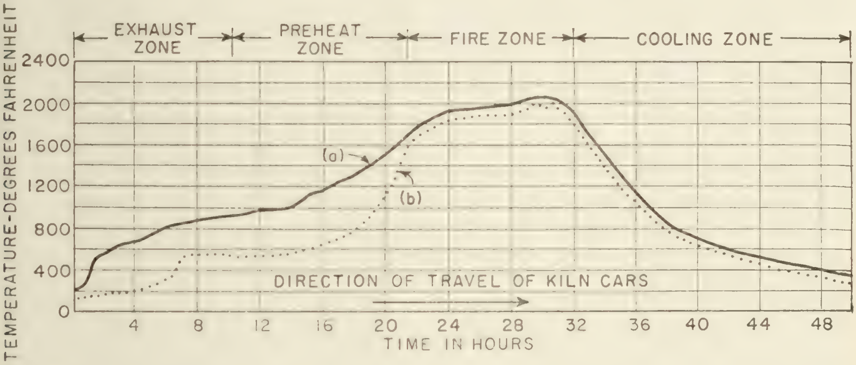

FIGURE 2. Results of traveling thermocouple test; (*a*), temperature at top of setting; (*b*), temperature at bottom of setting. Modified from M. P. Hall, fig. 6, Am. Ceramic Soc. Bull., March 1952.

In figure 2 are shown the results of this traveling thermocouple test. The temperature in the top of the setting jumped up very rapidly to more than 500°F, and after 4 hours was a little less than 700°F. By comparison the bottom couple had reached only 200°F in 4 hours. At about 6½ hours the bottom took a rapid jump from about 300°F to nearly 600°F and as the hot gases were pulled down through the setting and out the exhaust ports the effect was shown on the bottom temperature. The top temperature increased fairly uniformly—a little more rapidly as it approached the firing zone—while the bottom temperature held fairly constant for nearly 10 hours and then rapidly increased during the next 6 hours as the firing zone was approached. There was a spread of 500°F between the top and bottom couples throughout most of the pre-heat zone or, stated a little differently, between the bell and spigot of a 3-foot length of sewer pipe—500°F in 3 feet—a difference of nearly 15°F per inch of pipe. At the first firebox the difference had been reduced to about 100°F and through the fire zone the bottom temperature approached the top temperature very closely. The fluctuations in the temperature curves showed the influence of the individual fireboxes. In similar tests it has been found that the bottom temperature actually exceeds the top

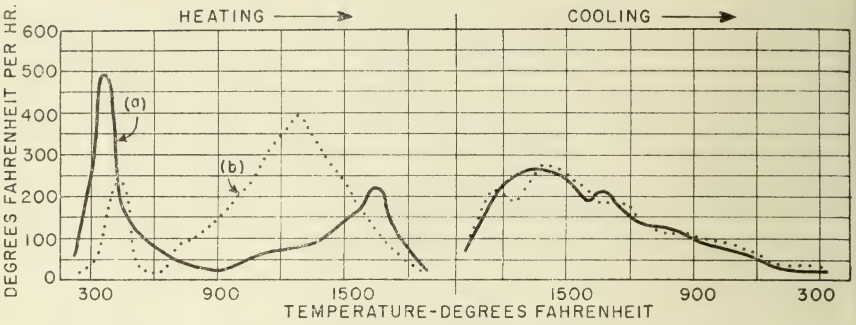

FIGURE 3. Rate of heating and cooling curves; (*a*), top of setting; (*b*), bottom of setting. Modified from M. P. Hall, fig. 7, Am. Ceramic Soc. Bull., March 1952.

temperature in the firing zone. In the cooling zone the top and bottom temperatures stayed close together. The firing of ware is similar to a trip in a car where the average speed may be 50 miles per hour but the actual speed will vary from 10 to 70 miles per hour. The actual speed of heating and cooling is plotted in figure 3. For example, one line represents 300°F per hour. That speed of heating might last for only 10 minutes for an actual change in temperature of 50°F, or it might last for an hour for an actual change of 300°F. The speed of heating or cooling is plotted against the temperature of the body. In the pre-heat zone both the bottom and top had periods of very rapid change in temperature but they occur in different points of the burning. The top was heating very rapidly at about 400°F, while the bottom did not reach this degree of heating until around 1200°F was reached. The cooling is important for sewer pipe. In this example it was relatively fast as it first came out of the fire zone, then it tapered off as it fell below 1200°F without extremes at any point in the cooling. During the heating period, presumably the pipe could be heated along a curve represented by the maximum of these two curves without subjecting it to any greater strain than we had in this example, provided both ends of the pipe could be kept at the same temperature. Fortunately the expansion curve for the material fired in this kiln shows only a small expansion up to about 1800°F and then rapid shrinkage. Because of these expansion characteristics, this kiln could be fired one-third faster if the temperature could be kept even. At least four cars could be added to the present fourteen-car schedule.

These curves (figs. 1, 2, and 3) have illustrated what was meant by the statement that we do a good job of firing the thermocouples. The crown couples resulted in a good firing curve, but the temperatures at different points in the ware were considerably different.

Abnormalities in firing can be caused by faulty pyrometric equipment as well as by the nature of the kiln. As previously described, a thermocouple measures the difference in temperature between the hot junction of the thermocouple and the cold junction. In a different tunnel kiln firing sewer pipe it was found that the absorption figures for the pipe were showing a wide range for no apparent reason. This situation was investigated by placing a cone plaque with a series of six cones and an absorption try piece on each car for 58 consecutive cars. The results are shown in figure 4.

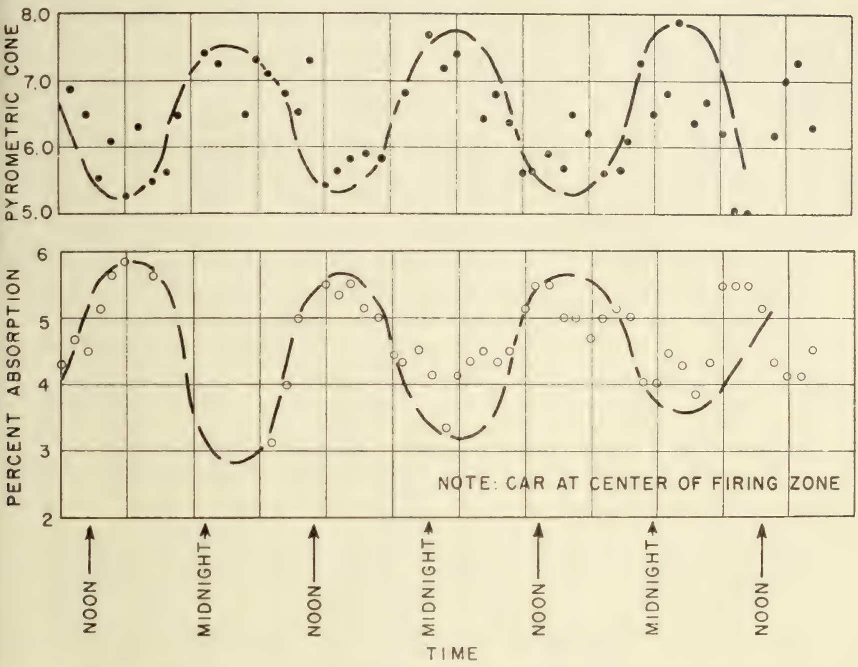

FIGURE 4. Tunnel kiln; cone deformation and absorption, 58 consecutive cars.

The relation between cone of firing and resultant absorption is readily apparent with high cone of firing resulting in low absorption. The question then was what caused the periodic fluctuation in temperature. This series was run during the middle of the hot month of August. The thermocouples in the firing zone were Pt-PtRh and the temperatures were controlled by the manual adjustment of the burners by the firemen. The thermocouples were connected to compensated lead wires at the thermocouple junction, but instead of this lead wire running straight to the measuring device, which was an indicating millivoltmeter, the lead wires extended to individual insulated boxes above the kiln and from there straight copper wire ran to the instrument. What happened then was this: that during the heat of the day the insulated box above the kiln would become quite hot, probably somewhere in the neighborhood of 150° to 200° F. When night came on, the whole plant would cool down with the boxes cooling perhaps 50° or more. Assuming that the temperature that the fireman was instructed to hold in the firing zone was 2000° F., in going from daytime to night-time the difference between the firebox temperature and the temperature of the insulated box would grow progressively less. The instrument not able to compensate for a change in the temperature of the cold junction would register a lower temperature for the firebox, and the fireman, seeing this decrease in temperature, would increase the fires to get back to an instrument reading of 2000° F. Going from night-time to daytime the situation would be reversed, and the fireman would be forced continually to change his fires to lower the instrument temperature reading to 2000° F. This is another good illustration of doing a good job of firing the thermocouples.

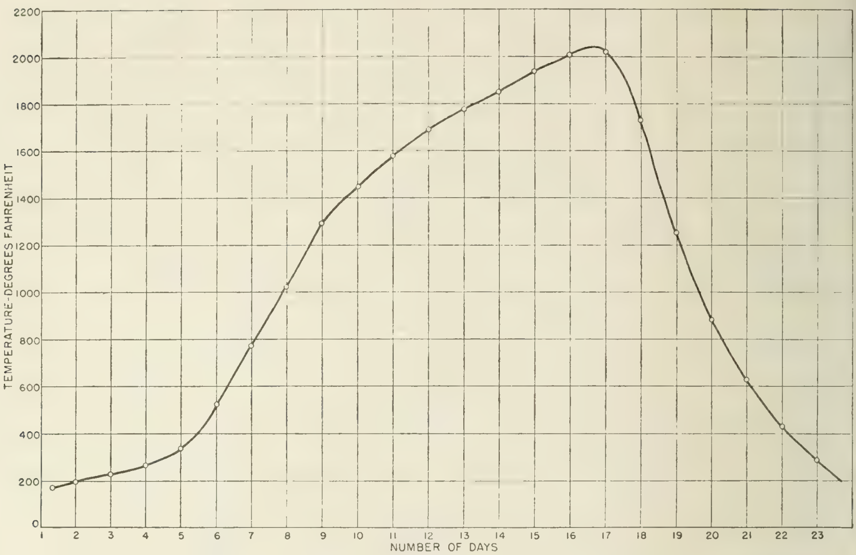

Figure 5. Typical firing and cooling curve for periodic kiln firing of 39-inch diameter sewer pipe.

The subject of temperature uniformity from top to bottom and from side to side in any kiln is always of considerable interest to the user of the kiln. In a firing survey of car tunnel kilns reported in the Journal of the American Ceramic Society (Nelson, M. S., and Wilson, H., 1942, pp. 237-240), the uniformity of firing of 45 kilns burning a wide range of products and using all types of fuel was reported as shown in table I.

Table I

Variation Range	No. of Kilns	Percent
1 or less cones	22	49
1 to 2	16	36
2 to 3	4	9
Above 3	3	6

The conclusion was given that of the 22 kilns showing one cone or less variation, 15 were small, indicating that better uniformity is usually obtained with kilns of small cross-section in which the heat penetrates easily to the middle of the load. It is doubtful, however, if one would build a tunnel kiln of small cross-section simply because he had a better statistical chance of getting improved uniformity.

PERIODIC KILNS

Periodic kilns, firing glazed ware, undoubtedly require the greatest uniformity. This is because some glaze colors vary considerably with variation in temperature. As mentioned previously, the heating-up period of periodic kilns burning terra-cotta ware is controlled by the thermocouple indication up to the point at which the first cones start coming down. In general the cone plaques in a terra-cotta kiln are made up of about 10 consecutive cones. For example, if firing to cone 8, cones 04, 02, 1, 2, 3, 4, 5, 6, 7, 8, and 9 are set up together in one plaque, and one such plaque is placed in each of the peepholes around the circumference of the kiln at generally two or more levels, one near the top of the setting and the other near the bottom. Thus there are from 12 to 16 cone plaques to control the progress of the firing. When the first cone starts to deform, the fireman has an opportunity to adjust the fires all around the kiln so that the cones deform uniformly. The cones in the top of the setting start to deform first, and as the higher numbers go down the fireman gives more and more attention to the kiln to level out the temperature variations. The cones near the bottom of the setting follow the top cones by two to three hours. Using our example of firing to cone 8, as soon as the top cones reach cone 8, the fires are cut back slightly to hold the kiln at that temperature as indicated by the thermocouple indication, and the heat is allowed to soak down until cone 8 comes down in the bottom of the setting. This procedure is accomplished without the bending of cone 9 in the top setting. The maturity of the burn is also judged by the appearance of glazed try pieces which are withdrawn from each peephole when it is believed that the kiln is finished. Thus, the uniformity of the burn from top to bottom is practically assured unless there is some mechanical difficulty with one of the burners or fireboxes which prevents that section of the kiln from attaining the proper temperature. The uniformity from the center to the outside of the kiln is generally fair, the difference in cones being in the neighborhood of one cone. Some glazes are more susceptible to deviation in firing than others and require setting in one section of the kiln to avoid undue color variation.

As an example of temperatures in periodic kilns firing unglazed ware, let us examine the data obtained during the firing of two large periodic kilns firing 39-inch-diameter sewer pipe. These pieces are among the largest of any ceramic article manufactured being about 4 inches in wall thickness, 4 feet long and requiring about 1¼ tons of clay. These data represent the composite of two kiln firings. Four Cr-Al thermocouples were placed in various positions among the ware as follows: In the first test one thermocouple was supported directly outside the protection tube in the kiln atmosphere so that the temperature of the control couple and that of the kiln gases surrounding the protection tube could be compared. A second thermocouple was placed almost directly under the first couple and about 5 feet above the kiln floor near the outside surface of one of the 39-inch pipes. A third thermocouple, close to the second couple, was buried in the sewer pipe as near the center of the section of the wall thickness as possible. The fourth thermocouple was placed under the preceding thermocouples near the surface of a pipe in the kiln atmosphere about a foot from the floor. All of these thermocouples were made long enough to extend through the kiln wall and were connected to a four point recording potentiometer. In the second test the thermocouple near the protection tube of the control couple was moved over to near the rear door so that it was close to the control cones, about 4 feet off the floor.

In general the progress of the heating and cooling curve looked like the curve in figure 5, which is typical of sewer pipe burns with the exception, of course, that the time has been considerably extended because of the heavy thickness of pipe. Instead of trying to plot curves of all of the thermocouples, which would come too close together on a drawing of this size, table 2 has been made to show the difference in

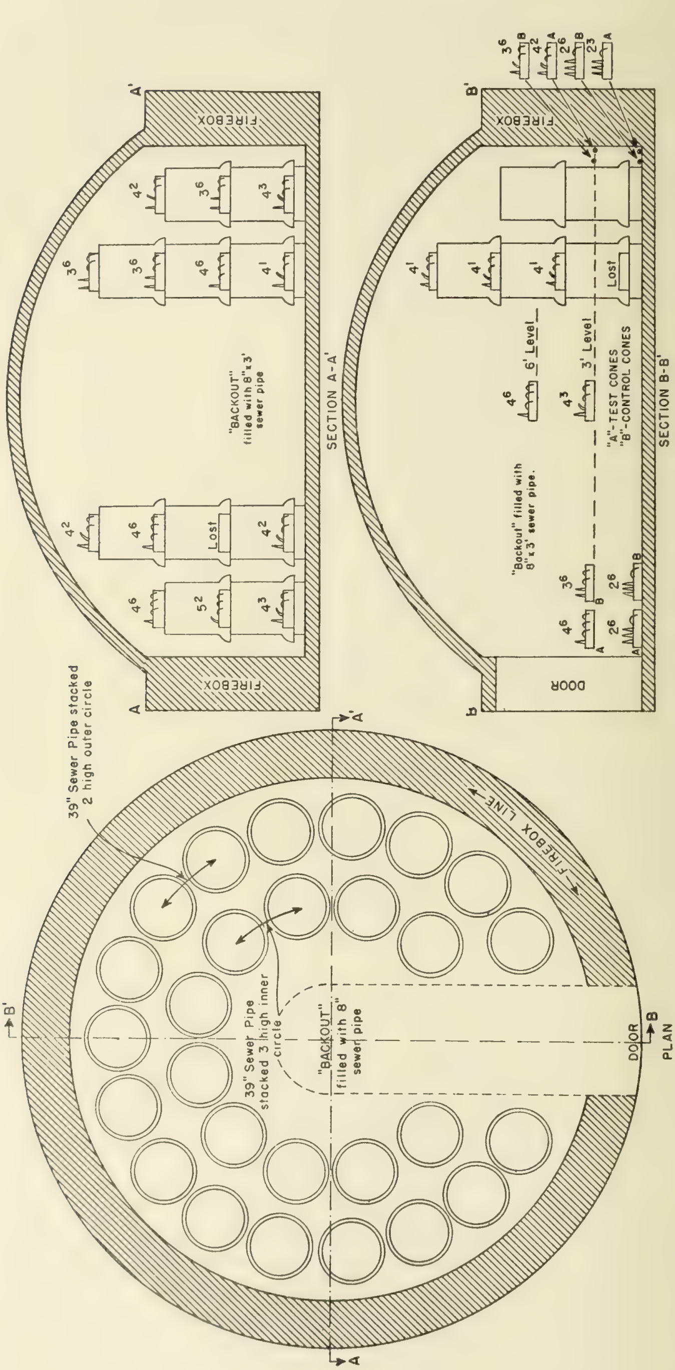
39" Sewer Pipe stacked 2 high outer circle
39" Sewer Pipe stacked 3 high inner circle
"BACKOUT" filled with 8" sewer pipe
FIREBOX LINE
DOOR
PLAN
A
A'
B
B'
FIREBOX
FIREBOX
4^6
5^2
4^3
4^6
4^2
Lost
4^2
"BACKOUT" filled with 8"x3' sewer pipe
3^6
3^6
4^6
4^1
4^2
3^6
4^3
SECTION A-A'
DOOR
"Backout" filled with 8"x3' sewer pipe.
4^6
2^6
3^6
2^6
A
B
4^6
6' Level
4^3
3' Level
"A"-TEST CONES
"B"-CONTROL CONES
SECTION B-B'
4^1
4^1
4^1
Lost
3^6
4^2
2^6
2^3
FIREBOX

FIGURE 6. Temperature variation in periodic kiln as shown by cones.

Table 2. Temperature differences between various points in periodic kiln.

Internal temperature	Rate of temp. increase °F/hr.	Temperature differences (in degrees F.)					
		A	B	C	D	E	F
170 to 225	1	25	50	30	10	30	10
225 to 400	4	45	90	50	15	45	20
400 to 800	10½	35	125	50	25	105	10
800 to 1400	9½	25	110	45	45	85	15
1400 to 2040	4	20†	35	35	15	15	*

A. Average difference in temperature between control thermocouple and 6 foot high thermocouple.
B. Average difference in temperature between control thermocouple and thermocouple near floor.
C. Average difference in temperature between control thermocouple and thermocouple near door.
D. Average difference in temperature outside and inside pipe.
E. Average difference in temperature over 4 feet of one pipe length.
F. Average difference in temperature between control couple and kiln gases around protection tube.
* Thermocouple failed.
† Temperature range 1400° to 1800° F.

temperature between the control thermocouple and the various test thermocouples in the kiln at different parts of the burn.

At the end of the burning period, during the temperature interval of about 2000° to 2040° F., there was a difference of only about 10° F. between the control thermocouple and the thermocouple at the floor. An interesting group of figures to note is the column showing the difference between the temperatures over the length of one piece of pipe (column E). This temperature difference varied from about 4° to 26° F. per foot which is remarkably uniform compared with the extreme of nearly 15° F. per inch of pipe which was discussed under tunnel kilns.

The final example of firing uniformity will show the variation in cones over another kiln of 39-inch sewer pipe. In addition to the two plaques of control cones set at each of the two doors, 24 plaques of test cones were set at various positions in the kiln as shown in figure 6. The uniformity of firing appears to be very good, there being a difference of one cone or less over the major portion of the working volume of the kiln.

REFERENCES

Hall, M. P., 1952, Tunnel kiln testing: Am. Ceramic Soc. Bull., vol. 31, pp. 85-88.

Nelson, M. S., and Wilson, H., 1942, Commercial firing survey of car-tunnel kilns; Am. Ceramic Soc. Jour., vol. 25, no. 9, pp. 237-240.

Sosman, R. B., 1938, Pyrometry and the steel-maker's refractories: Am. Ceramic Soc. Jour., vol. 21, no. 2, pp. 37-49.

PYROMETRY

By Ralph I. Brogie *

Of the many methods of measuring temperature that have been developed, the most satisfactory involve measurement of physical changes in a body resulting from temperature change. Some of these changes are: (1) Change in dimensions. This method utilizes a bimetallic strip in which one metal expands more than the other. It has low sensitivity. (2) Change in pressure when confined. Closed thermal system thermometers, vapor, gas or mercury filled, are examples. An

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* Minneapolis-Honeywell Regulator Company, San Francisco, California.

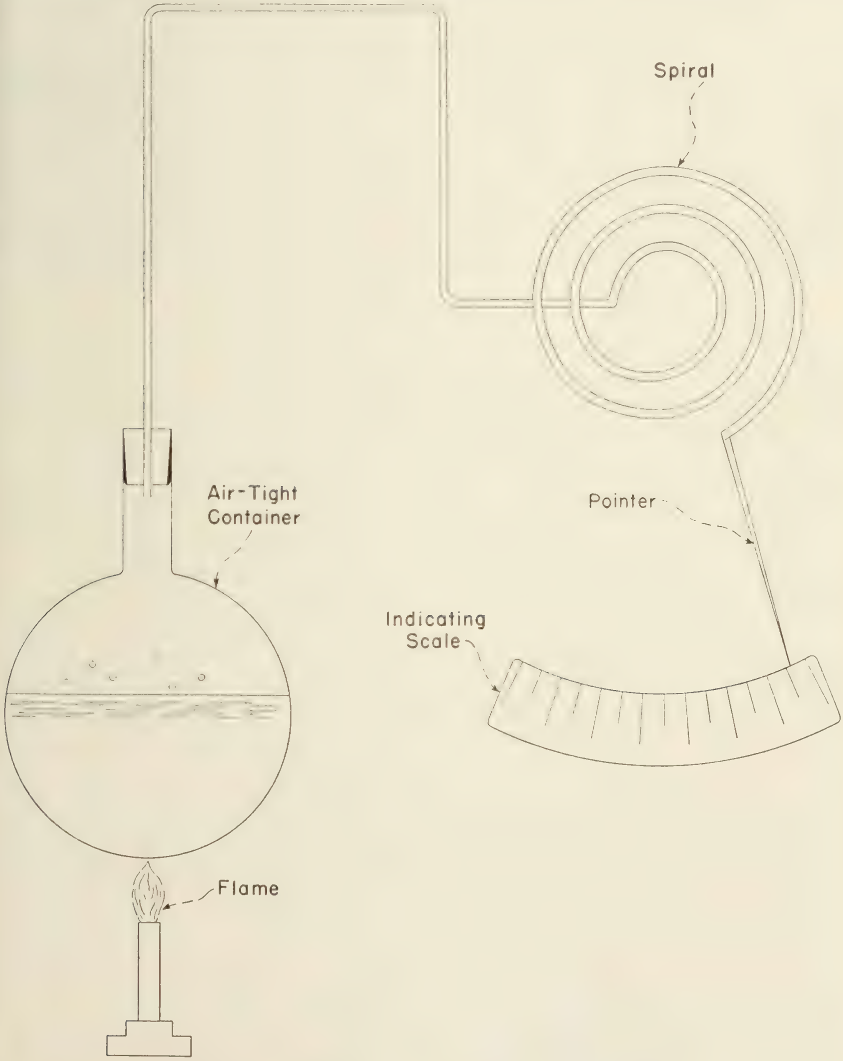

Figure 1. Principle of vapor-filled thermal system.

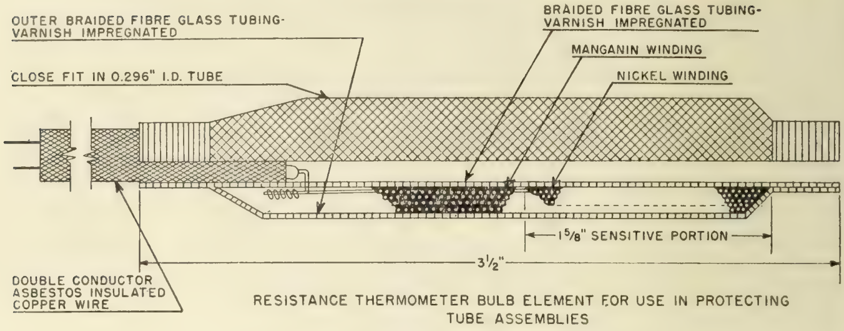
OUTER BRAIDED FIBRE GLASS TUBING-VARNISH IMPREGNATED
CLOSE FIT IN 0.296" I.D. TUBE
BRAIDED FIBRE GLASS TUBING-VARNISH IMPREGNATED
MANGANIN WINDING
NICKEL WINDING
1⅝" SENSITIVE PORTION
3½"
DOUBLE CONDUCTOR ASBESTOS INSULATED COPPER WIRE
RESISTANCE THERMOMETER BULB ELEMENT FOR USE IN PROTECTING TUBE ASSEMBLIES

FIGURE 2. Resistance bulb element.

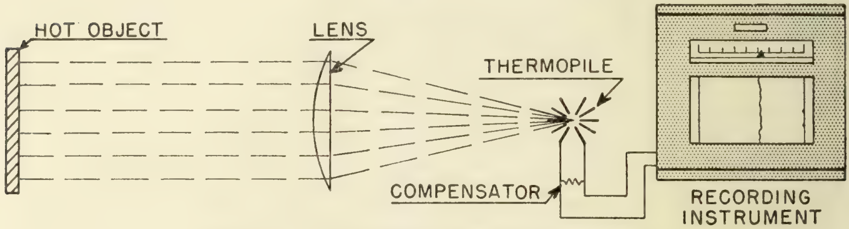
HOT OBJECT
LENS
THERMOPILE
COMPENSATOR
RECORDING INSTRUMENT

FIGURE 3. Principle of radiation pyrometer.

increase of temperature at the bulb (fig. 1) causes an increase in pressure that is transmitted through the capillary to the measuring spiral. Usual limits are from approximately —125° to +1000° F. (3) Changes in electromotive force. In a device known as a thermocouple, the junction of two dissimilar metals is heated, which causes a measurable emf that varies with the temperature. The emf is measured and translated into degrees of temperature by a millivoltmeter or potentiometer-type instrument. Temperatures in the approximate range —300° to +3200° F. can be measured. (4) Change in electrical resistance. Change in temperature causes a corresponding change in electrical resistance. The resistance of a coil of nickel wire, wound on a nickel core, is measured usually by an instrument with a Wheatstone bridge circuit, and translated into degrees of temperature (fig. 2). The usual limits of range of a resistance thermometer are —20° to +1000° F. (5) Change in radiant energy. Radiant energy emitted by a body varies with the temperature. A radiation pyrometer concentrates this energy by means of a lens on a thermopile as shown in figure 3. The emf developed by the thermopile is measured and translated into degrees of temperature in a potentiometer-type instrument. Temperatures from ambient to as high as 7000° F. can be measured in this manner. (6) Change in light intensity. Change in temperature causes corresponding changes in light intensity. This is measured with an optical pyrometer (illustrated in figure 4) by balancing the light intensity against a standard light source. Usual ranges are between 850° and 3600° F. (7) Change in physical state. Increased temperature will cause melting, vaporization, etc. which can be used to measure temperature. Pyrometric cones with carefully determined melting points will droop at specific temperatures. Usual range limits are from 1100° to 3600° F.

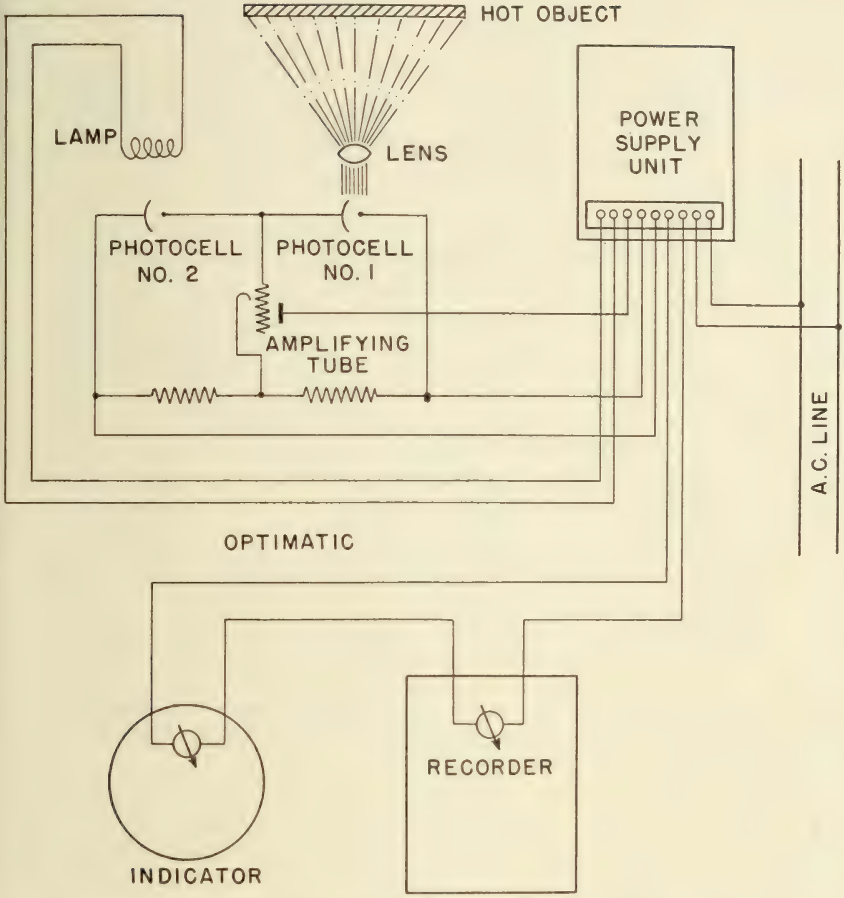
HOT OBJECT
LAMP
LENS
POWER SUPPLY UNIT
PHOTOCELL NO. 2
PHOTOCELL NO. 1
AMPLIFYING TUBE
A.C. LINE
OPTIMATIC
RECORDER
INDICATOR

FIGURE 4. Schematic diagram of optical pyrometer.

This discussion will confine itself to the thermocouple pyrometer and the radiation pyrometer—which are probably the two most widely used in the clay industries.

THERMOCOUPLE PYROMETERS

In 1821 Seebeck discovered that in a closed circuit composed of two dissimilar metals an electric current would flow when heat was applied to one of the junctions. For example, if the ends of an iron wire and a copper wire are fused together and one of the junctions is heated, positive current will flow in the direction copper to iron at the hot junction and in the direction of iron to copper at the cold junction (fig. 5).

The emf is produced in two ways. An emf develops between two different metals placed in contact; the magnitude of the force depends upon the temperature and upon the metals used. This is known as the Peltier emf. The second way, producing an effect known as the Thompson emf, is based on the fact that an emf is developed between the hot

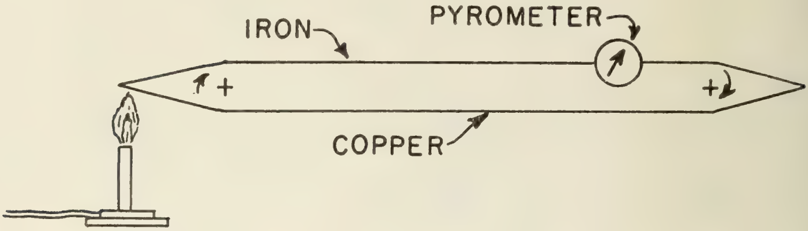

FIGURE 5. Seebeck's principle of flow of current in thermocouple.

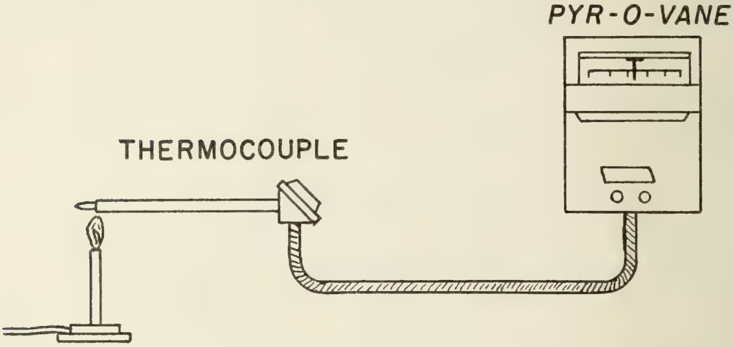

FIGURE 6. Diagram of a thermoelectric pyrometer.

and cold ends of a wire of one metal that is heated at one end; the magnitude of the emf depends upon the metal and upon the difference in temperature of the ends.

When two wires of different metals are joined together at one end and the free ends are connected by wires to a millivoltmeter or potentiometer, the instrument will indicate that a current is flowing when the junction of the two wires is heated. This is the basic principle of thermoelectric pyrometry (fig. 6).

Any two dissimilar metals could be used for a thermocouple. However, as certain combinations are most satisfactory, thermocouple wires are selected for these qualifications:

1. Capacity for resisting corrosion, oxidation, and crystallization.
2. Development of a comparatively large emf. The largest produced by any commercial thermocouple is about 50 millivolts, or 1/20 of a volt, at maximum usable temperature.
3. A temperature relation such that the emf increases fairly uniformly with increasing temperatures.
4. Cost.
5. Reproducibility.

In table 1 are the most common types of thermocouples and the emf developed at the highest temperature recommended for successful operation. Figure 7 shows the temperature limitations of common thermocouples and figure 8 shows the emf generated by thermocouples of various metals.

Table 1. Common thermocouples.

Composition of wires		Type	Emf for maximum operating temperature	
Positive	Negative		Millivolts	Degrees Fahrenheit
Platinum	Platinum 13 percent Rhodium	R	18.9	2,930
Chromel* (Nickel Chromium)	Alumel* (Nickel-Aluminum)	K	39.7	1,800
Iron	Constantan	J	41.7	1,400
Copper	Constantan	T	15.8	600

* Trade name, Hoskins Corporation.

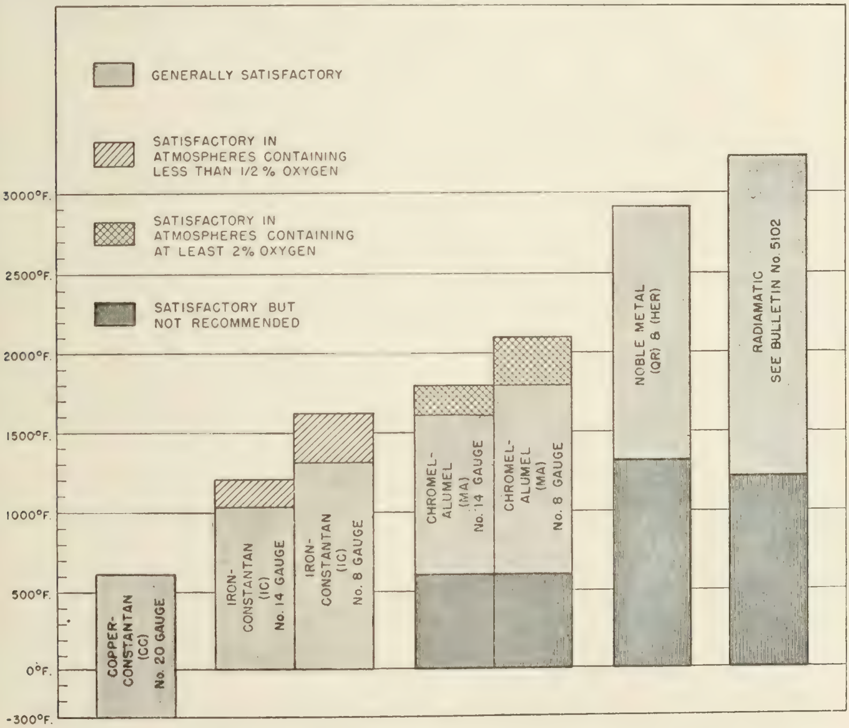

FIGURE 7. Temperature limitations of thermocouples.

Copper-Constantan thermocouples are generally used if the temperature ranges from subzero to 600° F. This type of thermocouple is recommended for oxidizing atmospheres. Iron-Constantan thermocouples are recommended to 1400° or 1600° F; however, they can be used to 2000° F if frequent replacements are made. Iron-Constantan thermocouples are recommended for use in reducing atmospheres.

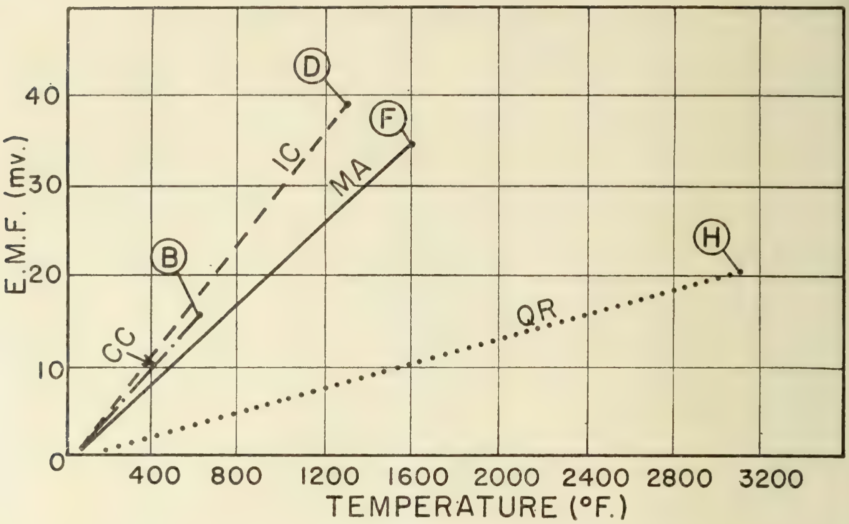

FIGURE 8. Temperature vs. emf calibration curves.

Chromel-Alumel thermocouples are recommended to 1800° F but can be used to 2400° F if they are frequently replaced. Chromel-Alumel thermocouples are recommended for oxidizing atmospheres.

Platinum-platinum-rhodium thermocouples are recommended to 2930° F but can be used to 3200° F. This type of thermocouple is recommended for either oxidizing or reducing atmospheres but care must be taken to protect the platinum from contamination or poisoning.

When the thermocouple is connected to the instrument the measuring junction or ''hot junction'' is at the end where the wires are joined and the reference ''cold junction'' is at the end of the thermocouple where the wires are not connected to each other.

The temperature indicated on the instrument will be the difference in temperature between the two ends of the thermocouple. If the temperature of the cold junction increases, the instrument will show a decrease in temperature, even though the furnace remains at the same temperature, because the temperature difference between the two junctions has been reduced. For this reason it is important that the cold junction be kept at constant temperature possibly by using an ice bath. If it is necessary to correct for changes in the temperature of the cold junction, several methods can be used. One is to design the instrument so that it compensates for changes in the temperature of the cold junction by acting to offset changes in ambient temperatures. In many millivoltmeter pyrometers there is a bimetal spiral on the pointer suspension. As the cold junction temperature increases, the bimetal spiral moves the pointer upscale to eliminate the cold junction error. In the potentiometer pyrometer, a resistor in the measuring circuit whose resistance changes with temperature variations, electrically counteracts the cold junction error. When extension leadwire is used to connect thermocouples to the pyrometer, the cold junction is extended to the instrument. Extension leadwires have thermoelectric properties similar

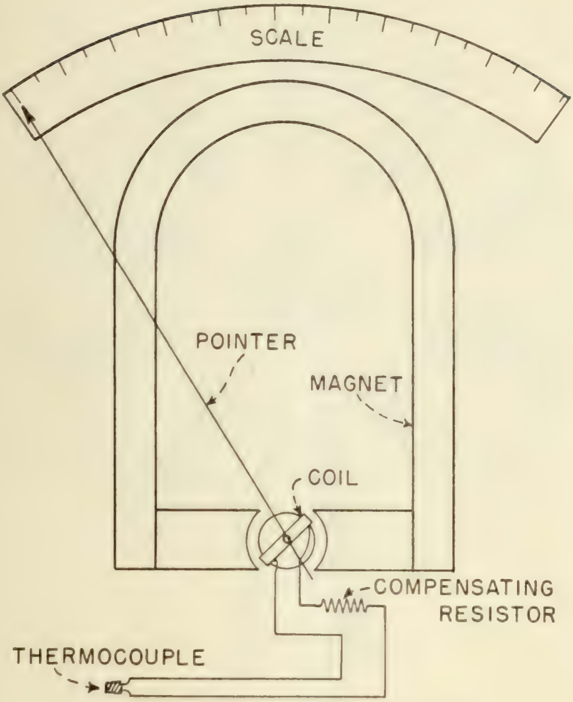
SCALE
POINTER
MAGNET
COIL
COMPENSATING RESISTOR
THERMOCOUPLE

FIGURE 9. Simple deflection pyrometer.

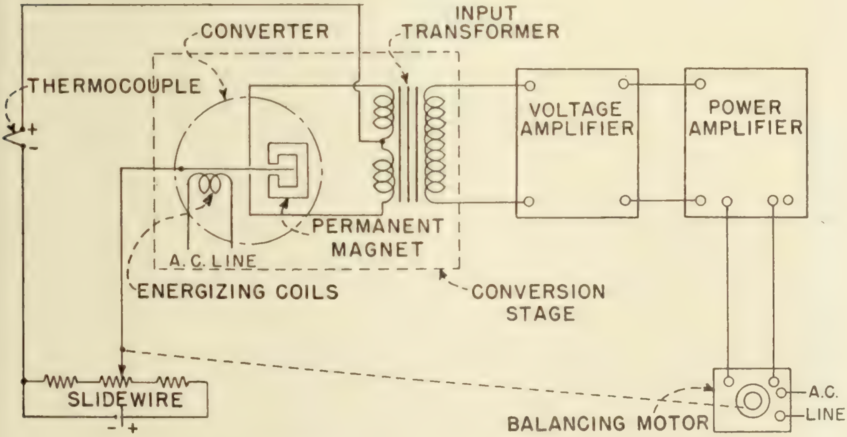
INPUT TRANSFORMER
CONVERTER
THERMOCOUPLE
+
-
VOLTAGE AMPLIFIER
POWER AMPLIFIER
PERMANENT MAGNET
A. C. LINE
ENERGIZING COILS
CONVERSION STAGE
SLIDEWIRE
- +
A.C. LINE
BALANCING MOTOR

FIGURE 10. Diagram illustrating continuous balance principle.

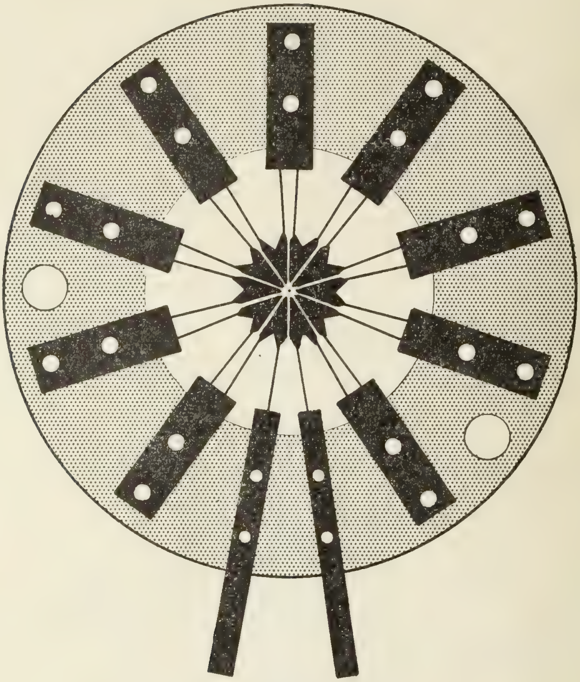

FIGURE 11. Radiamatic thermopile.

to those of the thermocouple with which they will be used. They are not interchangeable. For example, extension leadwire for use with Iron-Constantan thermocouples must not be used with Chromel-Alumel thermocouples, or serious errors will result. Suitable extension leadwires are available for the various thermocouples in general use.

The thermocouple emf can be measured by a millivoltmeter or a potentiometer. The deflection of a millivoltmeter can be compared to a spring scale in its operating principle, since the pointer is deflected in proportion to the millivoltage produced by the thermocouple. This type of instrument, illustrated in figure 9, has the advantage of low cost and simplicity, with an accuracy of about 1 percent of the full scale. The scale width is limited by the galvanometer movement. Instruments of this type are widely used in the heavy clay products and pottery industries.

The null balance or potentiometer type pyrometers function like a balance scale. The unknown millivoltage produced by the thermocouple is balanced against a known battery-produced potential and a galvanometer merely indicates when a balance has been obtained. The continuous balance potentiometer is illustrated schematically in figure 10. In the measuring operation, any unbalance of the potentiometer system is immediately detected, converted to A.C., and electronically amplified to drive a reversible balancing motor in the proper direction to restore the balance. Although the electronic principle greatly increases speed, sensitivity, and accuracy of temperature measurements, the major accomplishment as far as the ceramics industry is concerned is a mechanical simplification, freedom from the effects of vibration, and reduction of wear on moving parts. The potentiometer is capable of much greater accuracy than the millivoltmeter and since the pen and pointer are motor driven, a greater chart and scale length are obtained, resulting in better readibility. In the mechanically operated potentiometer a galvanometer deflects to show the magnitude and direction of unbalance between potentials. This unbalance is periodically detected by mechanical means which are used to rebalance the electrical system.

RADIATION MEASUREMENTS

The amount of radiant heat emitted from a body due to temperature changes can be measured by a radiation detector consisting of a lens and a thermopile enclosed in a suitable housing. The heat rays emitted from the hot object are focused by the lens upon a highly sensitive thermopile. The thermopile—a radial assembly of minute thermocouples wired in series to multiply the emf is connected to a potentiometer-type instrument (fig. 11). The amount of radiant energy received by the thermopile determines the temperature of its hot junction. On one type of instrument a nickel compensating shunt coil has been added in the thermopile circuit to eliminate ambient temperature errors. These instruments are calibrated under black body conditions; that is, under conditions in which all incident radiation is absorbed, and maximum amount is radiated, reflecting and transmitting none. This can best be illustrated by visualizing a hollow enclosure in which all objects are at a uniform temperature. If the radiation pyrometer is sighted upon the inner surface of this enclosure, it will receive the maximum amount of radiant energy for the existing temperature. No matter in what direction the radiation pyrometer is sighted within the enclosure the temperature reading will be the same. Most industrial furnaces are sufficiently enclosed to approach black body conditions except when cold charges are inserted. The increased use of the radiation principle in the measurement of temperatures is a modern trend in instrumentation, especially in the high temperature field. The ability to sight on target tubes from outside the furnace has eliminated the deterioration and contamination of rare metal thermocouples. In order to use this form of external temperature measuring element with a target tube, either open end or closed end, various accessory fittings are available. These include air-cooled fittings, protective safety shutter, and water-cooled fittings for extremely high ambient temperature.

Radiant energy emitted from an object within an enclosure (furnace or kiln) that is at a temperature different from that of the object, will be dependent upon the material and surface condition of the object. If temperature measurements are made under these conditions, part of the energy falling upon the receiver will be emitted from the object itself and the balance from the furnace walls by reflection. The radiant energy emitted by the object must be taken into consideration. Fortunately, most ceramic materials have relatively high and stable emittance values, and usually the material is similar to that of the surrounding wall, and has similar emittance characteristics.

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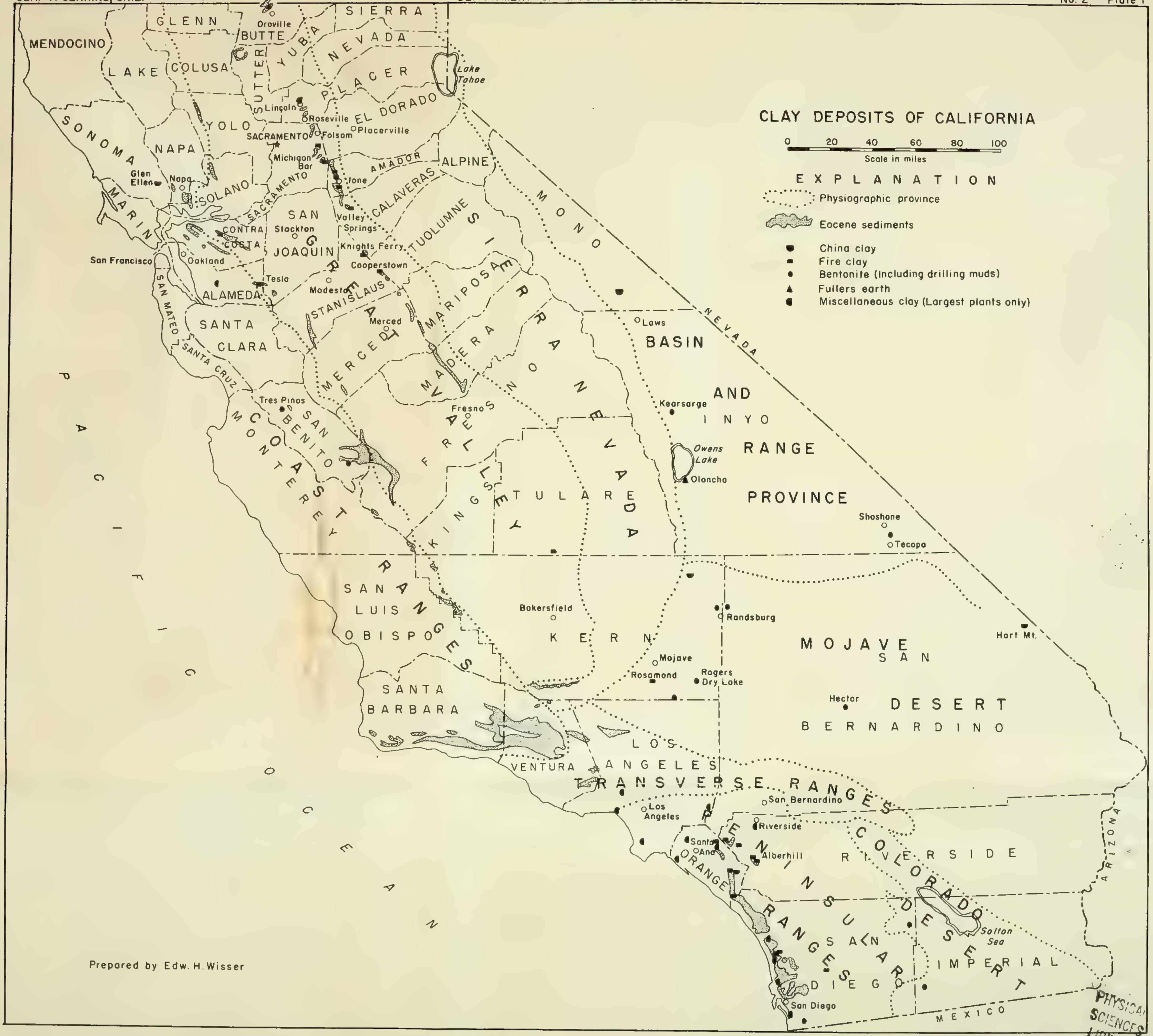

CLAY DEPOSITS OF CALIFORNIA

0 20 40 60 80 100
Scale in miles
EXPLANATION
Physiographic province
Eocene sediments
China clay
Fire clay
Bentonite (including drilling muds)
Fullers earth
Miscellaneous clay (Largest plants only)
PACIFIC OCEAN
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
LAKE
COLUSA
SUTTER
YUBA
PLACER
Lake Tahoe
SONOMA
YOLO
NAPA
SOLANO
MARIN
EL DORADO
AMADOR
ALPINE
SACRAMENTO
SAN JOAQUIN
CALAVERAS
TUOLUMNE
CONTRA COSTA
ALAMEDA
SAN MATEO
SANTA CLARA
SANTA CRUZ
STANISLAUS
MARIPOSA
MERCED
MADERA
MONO
FRESNO
SAN BENITO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
GREAT VALLEY
SIERRA NEVADA
COAST RANGES
BASIN AND RANGE PROVINCE
MOJAVE DESERT
TRANSVERSE RANGES
PENINSULAR RANGES
COLORADO DESERT
Oroville
Lincoln
Roseville
SACRAMENTO
Folsom
Placerville
Michigan Bar
Ione
Glen Ellen
Napa
Valley Springs
Stockton
Knights Ferry
Cooperstown
San Francisco
Oakland
Tesla
Modesto
Merced
Tres Pinos
Fresno
Laws
Kearsarge
Owens Lake
Olancha
Shoshone
Tecopa
Bakersfield
Randsburg
Hart Mt.
Mojave
Rosamond
Rogers Dry Lake
Hector
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Santa Ana
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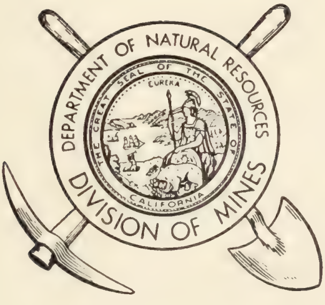

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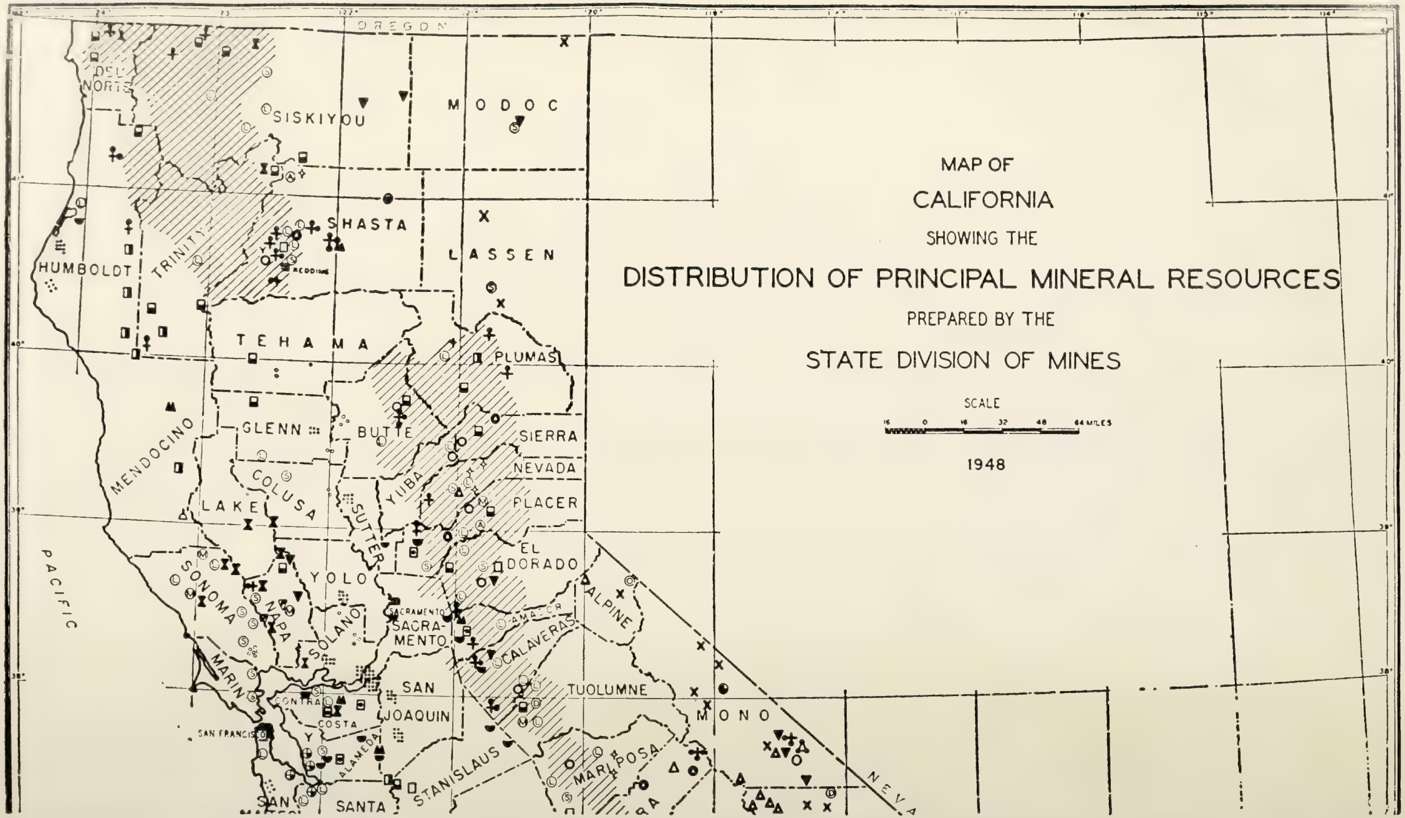
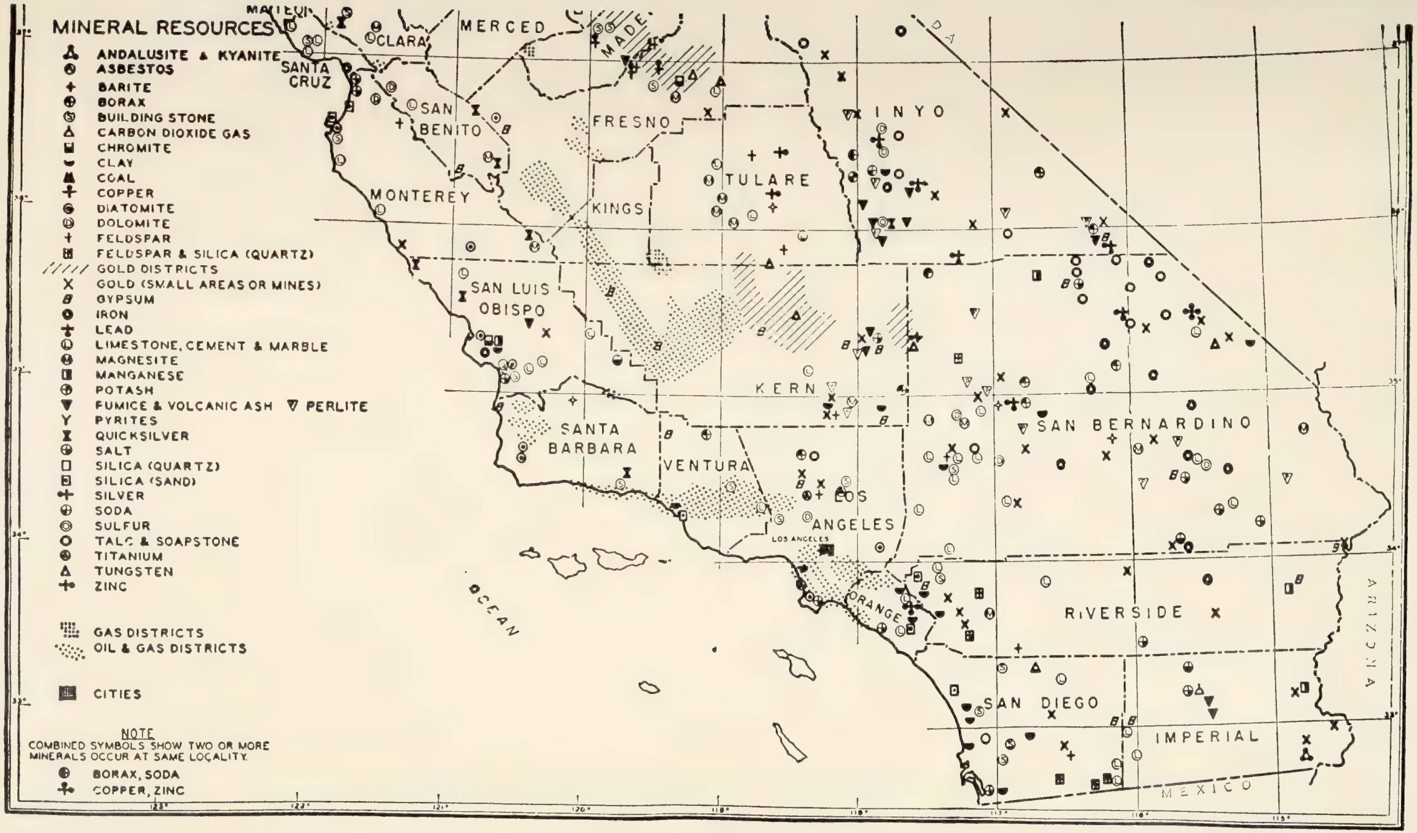


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES

SCALE

1948

16 0 16 32 48 64 MILES
OREGON
NEVA
PACIFIC
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
COLUSA
YUBA
PLACER
LAKE
SUTTER
EL DORADO
SONOMA
YOLO
NAPA
SOLANO
SACRAMENTO
SACRA-MENTO
ALPINE
AMADOR
CALAVERAS
MARIN
TUOLUMNE
SAN JOAQUIN
CONTRA COSTA
SAN FRANCISCO
MONO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY.
BORAX, SODA
COPPER, ZINC
MATEO
SANTA CRUZ
CLARA
MERCED
MADERA
SAN BENITO
FRESNO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
DA
122°
121°
120°
119°
118°
117°
116°
115°
35°
34°
33°

CONTENTS

Page

Lode Gold Mines of the Alleghany-Downieville Area, Sierra County, California, by Denton W. Carlson and William B. Clark ------- 237

History of Borax Production in the United States, by W. E. Ver Planck -- 273

PLATES

Plate 2. Map showing mine locations of the Alleghany-Downieville area--In pocket
3. Map of Brush Creek mine, showing Merritt and Cassidy workings --In pocket
4. Map of underground workings, Gold Bluff mine----------------In pocket
5. Map of underground workings of Irelan mine------------------In pocket
6. Cross-section, underground workings of Kate Hardy mine--------In pocket
7. Map of underground workings of Oriental mine----------------In pocket
8. Geologic map of Alleghany area, Sierra County, California------In pocket

LODE GOLD MINES OF THE ALLEGHANY-DOWNIEVILLE AREA, SIERRA COUNTY, CALIFORNIA

By Denton W. Carlson * and William B. Clark *

OUTLINE OF REPORT

Page
Abstract 237
Introduction 238
Geology 240
  Rock formations 240
  Veins 242
  Ore deposits 244
  Mineralization 245
Mining and milling 245
Mines active since 1942 247
References 267
List of mines 268

Illustrations

Plate 2. Map showing mine locations of the Alleghany-Downieville area In pocket
3. Map of Brush Creek mine, showing Merritt and Cassidy workings In pocket
4. Map of underground workings, Gold Bluff mine In pocket
5. Map of underground workings of Irelan mine In pocket
6. Cross-section, underground workings of Kate Hardy mine In pocket
7. Map of underground workings of Oriental mine In pocket
8. Geologic map of Alleghany area, Sierra County, California In pocket
Figure 1. Photo showing Tightner formation 239
2. Photo showing Sixteen-to-One vein 241
3. Sketch showing gold replacing quartz and arsenopyrite 243
4. Sketch showing arsenopyrite bordered and embayed by a single quartz crystal 243
5. Photo showing ore train entering Cassidy level, Brush Creek mine 247
6. Photo showing mine yard at Cassidy adit, Brush Creek mine 249
7. Sketch showing underground workings of Gold Crown mine 251
8. Photo showing Kate Hardy mine and mill 253
9. Photo showing Oriental mine yard 256
10. Oriental mill flowsheet 257
11. Oxford mill flowsheet 258
12. Map of underground workings of Oxford mine 260
13. Photo showing Red Star mine and mill 261
14. Red Star mill flowsheet 262
15. Photo showing Gold Crown mine yard and Sixteen-to-One mine and mill 263
16. Generalized cross-section of Sixteen-to-One vein, Sixteen-to-One mine 263
17. Map of underground workings, Sixteen-to-One mine 264
18. Sketch showing sequence of mineral deposition in Sixteen-to-One vein, Sixteen-to-One mine 265
19. Sixteen-to-One mill flowsheet 266

ABSTRACT

The Alleghany-Downieville area is one of the few remaining areas in California where lode gold mining is a major source of income. In 1953, more than $700,000 in gold was produced from the lode mines of the area. The total lode gold production from the Alleghany-Downieville region has been in excess of $50,000,000. Lode mines which have had the greatest amount of activity and production since World War II are the Sixteen-to-One, Brush Creek, Kate Hardy, Oriental, and Red Star mines.

The area, approximately 125 square miles in extent, lies on the western slope of the Sierra Nevada in southwestern Sierra County. It is characterized by rugged topography, and elevations range from 2,500 to 6,000 feet.

---

* Assistant Mining Geologist, California Division of Mines.

Bedrock in the area consists of steeply dipping, isoclinally folded metamorphosed volcanic and sedimentary rocks of Carboniferous and Permian age. Intrusive into these are Jurassic igneous rocks, chiefly ultrabasic rocks which have since altered to serpentine. Overlying the bedrock are gently west-dipping Tertiary and Quaternary volcanic and sedimentary rocks.

The Alleghany veins occur as quartz-filled fissures and replacement bodies in a fracture system that was formed principally by north-northwest-trending reverse faults. These veins dip east or west with the east-dipping veins tending to be flatter and more persistent. The Downieville veins dip steeply and contain larger amounts of sulfide minerals than the Alleghany veins.

The most characteristic features of the ore deposits in the Alleghany district are the extreme richness, very erratic distribution, and small size of the ore shoots. Most of the gold produced from the mines in the Downieville district has been from sulfide-rich ores, and a higher proportion of the gold occurs in relatively large but lower grade ore shoots than those in Alleghany. Certain favorable structural features control the ore deposition in the Alleghany veins. These include irregularities in the attitude of the vein and minor faulting. Serpentine commonly has had a direct influence in the location of highgrade ore.

The mineralization in the Alleghany district has been divided into four stages: Chlorite, quartz, carbonate, and final stages. During the carbonate stage, there was extensive replacement of the wall rocks by carbonate as well as deposition of the major portion of the gold. Economically the carbonate stage was the most important of all the stages.

In mining the Alleghany veins, the more favorable portions of the vein are cut up into small blocks by means of drifts and raises and the ore thus found is stoped. All of the mines are developed by adits. Little support timbering is required in the underground workings except in serpentine.

Gold ore is milled by crushing in jaw crushers, grinding in ball mills, gravity concentration, amalgamation, and flotation. Mill-head assays range from less than $5 to $30 or more in gold per ton. Mill recoveries range from about 80 to 96 percent. Most of the high-grade ore is milled separately.

INTRODUCTION

The Alleghany-Downieville district of Sierra County is one of the few remaining areas in California where lode gold is a major source of income. During 1953, the lode mines in this area produced more than $700,000 in gold. Since World War II, approximately 15 lode mines have been active at least part of the time. At present, the largest gold producers are the Sixteen-to-One and Brush Creek mines.

Gold has been produced from this area since the earliest days of California gold mining. Since 1907, the chief source of gold has been from the lode mines (MacBoyle, 1918, p. 1). Most of the lode production has been from small but rich ore shoots in the veins; relatively little gold has been obtained from the veins outside of the ore shoots. The total lode gold production from the Alleghany-Downieville area has been in excess of $50,000,000, most of which is based on a price of $35 per ounce.

Geography. The Alleghany-Downieville area is in southwestern Sierra County about 25 airline miles northwest of Grass Valley. Downieville, the county seat of Sierra County, and Alleghany, several airline miles to the south, are the principal towns in the area. Other towns include Goodyears Bar and Forest City.

State Highway 49 crosses the area from east to west and connects Downieville with Grass Valley, 50 miles to the southwest. Alleghany is connected to Goodyears Bar, which is 4 miles west of Downieville, by a 10-mile unpaved road. Alleghany is also served by the Ridge road, which extends 18 miles southwest along Pliocene Ridge to join State Highway 49, and the Foote road which runs west along the Middle Fork of the Yuba River and then south to North Columbia.

The region is drained by the southwest-flowing North and Middle Forks of the Yuba River and numerous subsidiary streams. All have cut deep canyons with steep walls. Elevations above sea level range from 2,500 feet in the canyons to more than 6,000 feet on the crests of the ridges. Downieville and Alleghany are at an elevation of 3,000 and 4,400 feet, respectively.

History. Gold has been produced in the Alleghany-Downieville area since 1849. Soon after the beginning of the California gold rush, rich discoveries along the many streams attracted thousands of gold seekers to the area. Among them was William Downie who established a settlement known now as Downieville. Sierra County was established in 1852. The river bars were mined first, after which hydraulicking and drift mining of the buried auriferous channels were done. The peak of the early production at the Alleghany area was about 1861 (Ferguson and Gannett, 1932, p. 25). Subsequently, the more deeply buried gravel deposits of the Forest district were exploited.

Lode gold mining began in the area in 1853 (Ferguson and Gannett, 1932, p. 26), and during the 1870's, such lode mines as the Plumbago and Brush Creek produced substantial amounts of gold. The rediscovery of the Tightner vein in 1907 caused a revival of lode gold mining in the area, which is now continuing. The greatest year of lode gold production for the district was in 1922 when $1,710,521 were produced (Ferguson and Gannett, 1932, p. 27). In the late 1930's, drift mining was revived with such mines as the Ruby contributing substantially to the total gold production of the area.

In 1942, War Production Board Order L-208 was placed in effect and all of the gold mines either shut down or remained open under limited operation. Since World War II, some of the mines have resumed operations on a scale as great as that prior to the war. The

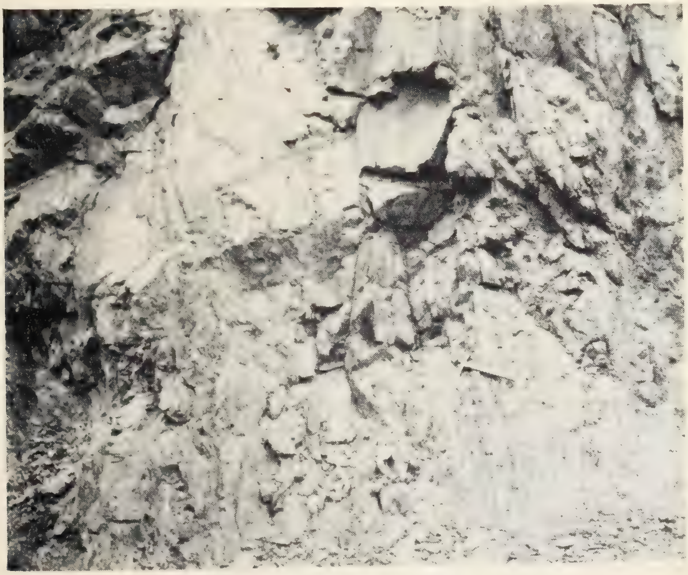


FIGURE 1. Road cut exposing Tightner formation near Red Star mine.

post-war increase in wages and material costs coupled with a fixed price of gold and the expense of reconditioning idle mines have caused a number of the mines to remain idle. Former important lode mines now idle include the Rainbow and Plumbago.

GEOLOGY

The oldest and most extensive rocks of the region are a series of metamorphosed sedimentary and volcanic rocks of the Calaveras group (Carboniferous, in part). They have a north to northwest trend, dip steeply east, are isoclinally folded and in part overturned to the west. In this area the Calaveras group has been divided into five formations of which three, the Blue Canyon, Relief, and Cape Horn, were mapped and described by Turner (1897) and Lindgren (1900) and two, the Tightner and Kanaka, were mapped and described by Ferguson and Gannett (1932, pp. 6-12).

Intrusive into the Calaveras group are ultrabasic and basic igneous rocks and small amounts of granitic rocks. Virtually all of the ultrabasic igneous rocks have been altered to serpentine.

Overlying the Calaveras group and granitic and basic igneous rocks, especially on the interstream ridges, are nearly flat-lying auriferous gravels (Eocene to Miocene), andesitic breccia (Mio-Pliocene), basalt flows (Pleistocene), and minor amounts of stream gravels (Pleistocene to Recent).

Rock Formations

Calaveras Group (Carboniferous in Part)

Blue Canyon Formation. The Blue Canyon formation occurs extensively in beds of great thickness east of the Alleghany-Downieville area and is the basal formation of the Calaveras group in the area.

The formation is composed chiefly of dark slate which becomes nearly white on weathering. In places, the slate grades into micaceous schist. Present in small amounts are fine-grained quartzite, impure limestone, and fine-grained conglomerate. The formation dips steeply west and its strike is northwest at a slight angle to the fault contact that bounds it on the west.

Tightner Formation. The Tightner formation occurs in both the central portion of the Alleghany district and in the Downieville district. At Alleghany, the Tightner formation is in fault contact with the underlying Blue Canyon formation to the east and is conformably overlain by the Kanaka formation to the west.

The formation consists predominantly of massive beds of greenish hornblende-chlorite schist with varying amounts of quartz. Also present are minor amounts of carbonaceous slate, coarse white limestone, quartz, andalusite, and chlorite-mica schist.

Kanaka Formation. The Kanaka formation is exposed west of the Tightner formation and conformably overlies it. The Kanaka is exposed in a 1,600-foot-wide belt just west of Alleghany, on Oregon Creek west of Forest, and along State Highway 49 east of Goodyears Bar.

There are three members of the Kanaka formation. The basal member on the east is composed of a metamorphosed conglomerate of andesite and quartzite pebbles and cobbles in a matrix of black slate. Overlying the conglomerate is the chert member which consists of banded

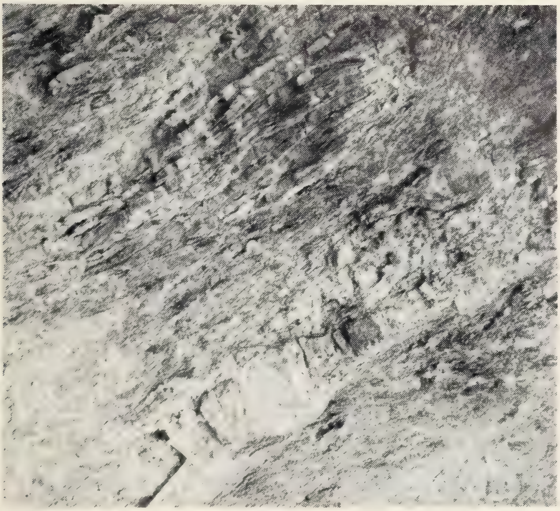


FIGURE 2. Road cut exposing Sixteen-to-One vein in conglomerate member of the Kanaka formation.

and contorted gray chert with interbedded black slate and fine-grained quartzite. The upper member is composed of successive beds of slate and greenstone.

Relief Formation. Small and scattered beds of siliceous metasediments lying between the Kanaka and Cape Horn formations in the Alleghany area are believed to be a north extension of the Relief quartzite (Ferguson and Gannett, 1932, p. 12). These beds are composed essentially of dark fine-grained quartzite and quartzitic mica schist.

Cape Horn Formation. The uppermost member of the Calaveras group in the area is the Cape Horn slate which occurs in a north-trending belt 1 to 2 miles wide along the western portion of the area. The formation is composed chiefly of dense black clay-slate with interbedded thin bands of light-colored volcanic material.

Igneous Rocks

Serpentine. Two large masses of serpentine extend along the eastern and western portions of the area, and many smaller masses lie between them. Serpentine is an alteration product of deep-seated ultrabasic igneous rocks of Jurassic (?) age. Serpentinization was prior to the formation of the quartz veins. Serpentine, if near a gold-bearing quartz vein, has a marked effect on the character of the ore deposit. (See section on ore deposits.)

The serpentine ranges from light to dark green in color and contains light-colored shear planes. Magnetite and occasionally chromite are present. Serpentine, under the influence of vein-forming solutions, has been replaced by carbonate (chiefly ankerite) and mariposite. Further alteration in places has produced talc.

Gabbro, Diorite, Quartz Diorite. Dark-colored granitic rocks ranging in character from amphibolitic rocks derived from gabbro to schistose diorite and quartz diorite are found in much of the area.

Extensive outcrops occur east of Downieville, south of Goodyears Bar, and immediately west and south of Alleghany. Numerous smaller masses are found in the area, expecially in areas occupied by the Tightner and Kanaka formations.

These intrusive rocks are composed chiefly of hornblende and alteration products of feldspar with smaller amounts of quartz, pyrrhotite, biotite, and olivine. The general trend of these rocks follows the strike of the older formations, but where contacts are exposed the older schistosity is cut by the gabbro. A post-Carboniferous (probably Jurassic) age has been assigned these rocks by most writers.

Medium and Light-Colored Granitic Rocks and Aplite. A moderate-sized mass of granite crops out 5 miles southwest of Goodyears Bar. A zone of small, altered granite stocks and dikes occurs in the central portion of the area. There also are a few small dikes of aplite in the Alleghany area. The large granitic bodies of the Sierra Nevada batholith lie approximately 5 miles east and 10 to 15 miles west of the area.

Neither the granite masses nor the aplite dikes are schistose. The granites are medium grained and are composed essentially of quartz and feldspar. The principal accessory mineral is biotite but it is generally not abundant. The aplite dikes are fine grained and are of similar composition to the granite.

The granites and their satellites are generally believed to be of Upper Jurassic or Lower Cretaceous age.

Tertiary Rocks

The oldest Tertiary rocks in the area are river gravel deposits of Eocene age. These are characterized by an abundance of quartz pebbles and are rich in placer gold. Overlying the Eocene gravels are Miocene intervolcanic river gravels. These deposits contain an abundance of volcanic rocks, mainly rhyolite and andesite.

Large masses of volcanic breccia of the Mehrten formation (Mio-Pliocene) cap the interstream ridges in the area. The breccia is composed of angular and water-worn fragments of andesite loosely set in a matrix of finer andesitic debris.

Dense fine-grained olivine basalt (Pleistocene), which represents a succession of flows, crops out in the area, notably on the summit of Bald Mountain at Forest. Pleistocene and Recent gravels occur in and near the present stream channels.

The Tertiary rocks invariably are gently dipping and lie with distinct angular unconformity upon the older stratified rocks.

Veins

The veins of the Alleghany area are quartz-filled fissures and replacement bodies in a fracture system that was formed principally by north-to-northwest-trending reverse faults. A few of the veins have followed probable normal faults. Dip is moderately east or west with the east-dipping veins tending to be flatter and more persistent. The veins are well defined, vary greatly in width, and are generally irregular in strike and dip. Average width of the major veins is from 5 to 6 feet, but there is considerable variation in vein dimensions.

The veins were formed prior to deposition of the Eocene auriferous gravel and after the intrusion of the granitic rocks. The veins are closely related to the granitic rocks and were formed near the end of

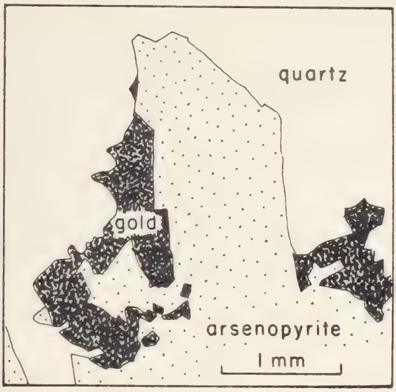


FIGURE 3. Sketch showing gold replacing quartz and arsenopyrite (after Ferguson, 1915, p. 165).

late Jurassic time. The veins were formed many thousands of feet below the land surface of that time.

Quartz veins occur in all of the pre-Tertiary rocks of the area except the larger serpentine masses. Generally, none of the veins penetrate the larger serpentine masses, but some abut against them. Where the fissures extend into the serpentine, the vein frays into small stringers which grade into a replacement mixture of mariposite and carbonate (chiefly ankerite).

Ribbon structure, which is so characteristic of the Alleghany veins, implies a banded or streaked appearance occasioned by slabs or thin sheets of country rock or other material interlayered with quartz in the veins. Some of the ribbons are straight and generally parallel to the walls while others are irregular. The irregular structures are known as crinkly banding. Carbonate material (chiefly ankerite) predominates in the vein filling while other common minerals are micas and sulfides. Ferguson and Gannett (1932, p. 36) attributed the formation of ribbon

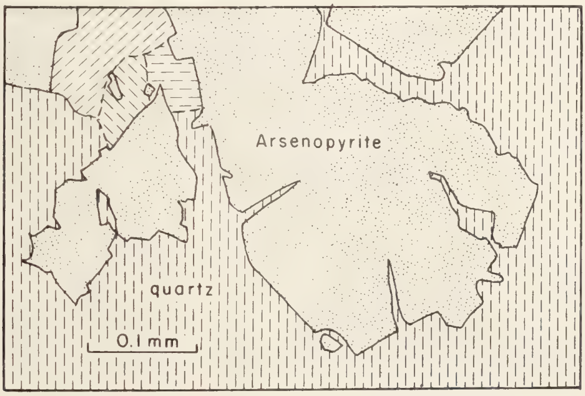


FIGURE 4. Sketch showing arsenopyrite bordered and embayed by a single quartz crystal, seen by polarized light. The different quartz crystals are indicated by the directions of the broken lines. (After Ferguson, 1915, p. 167.)

quartz to accretion where later fracturing was followed by deposition of still later minerals along closely spaced planes. McKinstry and Ohle (1949, p. 108), however, conclude that ribbon structure results almost entirely from replacement. Cooke (1947, pp. 229-232) in a study of the Sixteen-to-One vein, believes that a combination of accretion and replacement was responsible for the ribbon structure.

The quartz veins of the Downieville area are fissure and replacement veins, ranging in strike from northwest to northeast and dipping moderately to steeply east. Width of the veins ranges from 2 to 10 feet. These veins have a higher sulfide content than the Alleghany veins.

Ore Deposits

The most characteristic feature of the ore deposits in the Alleghany district is the extreme richness, but very erratic distribution and commonly small extent of the ore shoots. Most of the gold produced from mines in the vicinity of Downieville has been from sulfide-rich ores whereas those at Alleghany contain a much larger proportion of free gold.

At Alleghany, the high-grade ore shoots range in size from small bunches yielding a few hundred dollars to those which have yielded hundreds of thousands of dollars. An ore body at the Sixteen-to-One mine, which was about 40 feet long, contained nearly $1,000,000 in gold while an area 14 by 22 feet as seen in section in the vein of the Oriental mine yielded $736,000 (Ferguson and Gannett, 1932, p. 52). Quart-vein matter outside of the shoots is nearly barren of gold and mill-head assays commonly yield $5 per ton or less in gold. Although the quartz adjacent to a high-grade shoot generally is barren, it has been found that the change may be less abrupt in one or more directions than the others, and along these courses the quartz may contain more gold than the average vein quartz outside of the shoots (Ferguson and Gannett, 1932, p. 52).

At Alleghany the high-grade ore rarely extends across the width of the vein, but is usually confined to strands near the footwall or the hanging wall. Veins with an easterly dip have been the chief source of gold in the area. However, in the past few years west-dipping veins at the Brush Creek and Kate Hardy mines have proved important.

There are certain favorable structural features associated with high-grade ore deposits in the Alleghany district. Any irregularity in the vein caused by changes in dip and strike, sudden swellings, junctions or splits in the vein, and minor faults are the principal favorable locations for the deposition of high-grade ore shoots. The influence of large serpentine masses is of importance as the veins tend to bend toward parallelism with the serpentine contact. Much of the production of mines near serpentine come from that part of the vein within the bend. Smaller serpentine dikes appear to have some influence also on localization of high grade ore.

The presence of visible free gold is of great importance in tracing shoots of high-grade ore, as there is commonly at least one direction in which the change to barren quartz is not as sharp as in the other directions. Coarsely crystalline arsenopyrite is also of importance in finding ore shoots as this mineral seems to have been effective in causing the deposition of gold. In some places the arsenopyrite is partly replaced by gold (Ferguson and Gannett, 1932, p. 59). The presence of mariposite or "blue-jay" is sometimes significant as it is most abundant near serpentine, and the presence of that rock has had considerable control over the location of high-grade ore shoots.

In the vicinity of Downieville, a higher proportion of the gold occurs in relatively large, but lower grade ore shoots as compared with those in the Alleghany area. The gold occurs in quartz veins, and occasionally in contact metamorphic rocks closely associated with sulfides, chiefly pyrite. Subordinate amounts of arsenopyrite, galena, chalcopyrite, and sphalerite are commonly present. Ore produced from the Gold Bluff mine in 1938 averaged $10 per ton in gold (Averill, 1942, p. 28), while ore from the Oxford mine ranged in value from $10 to $15 per ton (Huelsdonk, L. L., personal communication, 1954).

Mineralization

On the basis of studies made on thin sections, Ferguson and Gannett (1932, pp. 38-51) have divided mineralization in the Alleghany area into four stages—the chlorite, quartz, carbonate, and final stages.

The earliest stage of mineralization is the chlorite stage. This stage, which was probably on a regional scale, consisted essentially of the chloritization of the hornblende of the schists and altered gabbro. Partial serpentinization of the peridotite and pyroxenite belong to this stage.

The quartz stage followed, during which fissure filling by quartz and quartz replacement of the wall rock occurred. Radiating crystals of arsenopyrite, which formed the nucleus for later deposition of native gold, and pyrite were deposited in the fissures and veins, both slightly earlier than and contemporaneous with the quartz. Other minerals formed during this stage were plagioclase, barite, apatite, and beidellite in small amounts.

The carbonate stage followed the quartz stage. During this, there was extensive replacement of the wall rocks by carbonate (chiefly ankerite), sericite, mariposite, and minor amounts of chlorite, arsenopyrite, and pyrite. Some earlier quartz was partially replaced. In the fissures, native gold, along with sericite, carbonate, mariposite, and several sulfide minerals, replaced the earlier quartz. The earlier brecciated quartz of the quartz stage was recemented by later quartz of the carbonate stage. Economically, the carbonate stage was the most important of all the stages.

In the final stage, small amounts of uneconomic minerals including calcite, finely crystalline pyrite, and possibly marcasite, were deposited as small veinlets or as coatings on drusy quartz.

MINING AND MILLING

As the high-grade ore of the Alleghany gold mines is sporadic in distribution a close correlation between favorable geologic conditions and development work must be exercised. Ore bodies are easily missed unless the veins are thoroughly explored. The discovery of ore shoots and isolated bunches of ore, as practiced now, is made by cutting up the more favorably situated portions of the vein into small blocks by means of drifts and raises, and stoping the ore thus blocked out. The mining of large amounts of nearly barren quartz to avoid missing high-grade bunches is thus avoided.

Most of the lode-gold mines of the Alleghany-Downieville area are worked through adits and winzes on the veins. A few mines were originally developed by inclined shafts from the surface although none are used at the present time. Levels are generally established at intervals of 100 to 200 feet. The ground between the levels is developed by raises and often intermediate drifts.

Underground excavation entails drilling, blasting, and timbering as required. Ingersoll-Rand stopers and Swedish-Atlas Copco jackleg drills are most commonly used in mining and development work. In some cases stopers mounted on air bars or rail-mounted hydraulic jibs are utilized in drift and crosscut headings. Bits equipped with tungsten-carbide inserts are commonly used. Slushers are used for handling the muck and ore in intermediate and flat raises and pneumatic mucking machines on the drift and crosscut headings.

Very little support timbering is required in the underground workings except where the country rock consists of serpentine. Because of the tendency of serpentine to swell upon exposure to air, much timbering is required.

Because most of the mines are developed by adits and underground shafts, underground hoists are used. Tramming of the ore cars generally is done by storage-battery locomotives.

Milling-grade ore in the area is processed by crushing and grinding, gravity concentration, amalgamation, and flotation. Mill head assays range from less than 5 dollars to 30 dollars or more in gold per ton. Mill recoveries range from about 80 to 96 percent.

Gold ore is first crushed by a jaw crusher and then wet-ground in a ball mill. Stamp mills were once used in secondary crushing, but their size, power consumption, and other economic factors, as compared with those of ball mills, have rendered them obsolete. None are used in the mills of this area. Jaw crushers reduce the ore to a convenient size for the ball mill feed. Particle sizes coming from the jaw crushers range from minus-$\frac{3}{4}$ to minus-2 inches while ball mills further grind the ore to sizes ranging from minus-6 to minus-65 mesh for tabling, and to minus-100 mesh for flotation.

The finely ground ore is then sent to gravity-concentrating devices, including jigs and hydraulic traps. Overflow from the jigs and hydraulic traps flows into spiral or rake classifiers. Sands from the classifier are usually reground in the ball mills, and introduced again through the mill circuit. Slime products from the classifier may be sent to either concentrating tables or to a flotation unit. Scalping screens are utilized in the mill circuits in certain cases.

Concentrating tables, which include several types, are shaking tables, each equipped with a series of riffles. Water is allowed to flow down the slope of the tables and aids in gravity separation. Several tables are usually used in series so as to minimize the gold loss from the fine particles. Concentrates from the tables generally are sold to the smelter at Selby.

To minimize a further gold loss, particularly where the gold is in intimate aggregation with the sulfide minerals, the slimes are directed into flotation cells. The gold-bearing sulfide concentrates produced from flotation are usually sold to the smelter at Selby or the Empire Star mine in Grass Valley. In one instance, the flotation concentrates are sent to a thickener for dewatering.

High-grade gold ore is handled separately and not processed in the mill. Such ore is crushed in laboratory-sized rod mills, gyratory crushers, or rolls. The gold is amalgamated in amalgamating barrels or Berdan pans, retorted, and the bullion is sold to the U. S. Mint in San Francisco.

MINES ACTIVE SINCE 1942

With the onset of World War II, high wages, scarcity of materials, and the departure of men to engage in defense activities or to serve in the armed forces, caused gold mining in this region to be severely curtailed. War Production Board Order L-208, which was issued on October 8, 1942, in effect ordered all gold miners to go into other types of mining. Most of the gold mines of the Alleghany-Downieville area were closed during the war. The Sixteen-to-One mine was operated on a limited basis under a special grant issued by the War Production Board.

Order L-208 was lifted on July 1, 1945. The Sixteen-to-One mine resumed normal operations soon afterward, and in 1946, the Brush Creek and Oriental mines were reopened. Lode gold mining in this area, however, has not been resumed on a scale equal to that before World War II.

Lode mines which have had the greatest amount of activity and production since the war are the Sixteen-to-One, Oriental, Brush Creek, Kate Hardy, and Red Star mines. Others in which there has been some activity and production include the El Dorado, Eureka, Gold Bluff, Gold Crown, Irelan, Mugwump, Oxford, and Seven Aces mines.

Brush Creek Mine. Location: Secs. 17, 18, 19, T. 19 N., R. 10 E., M. D. M., 1½ miles south of Goodyears Bar. Ownership: Alpha Hard-

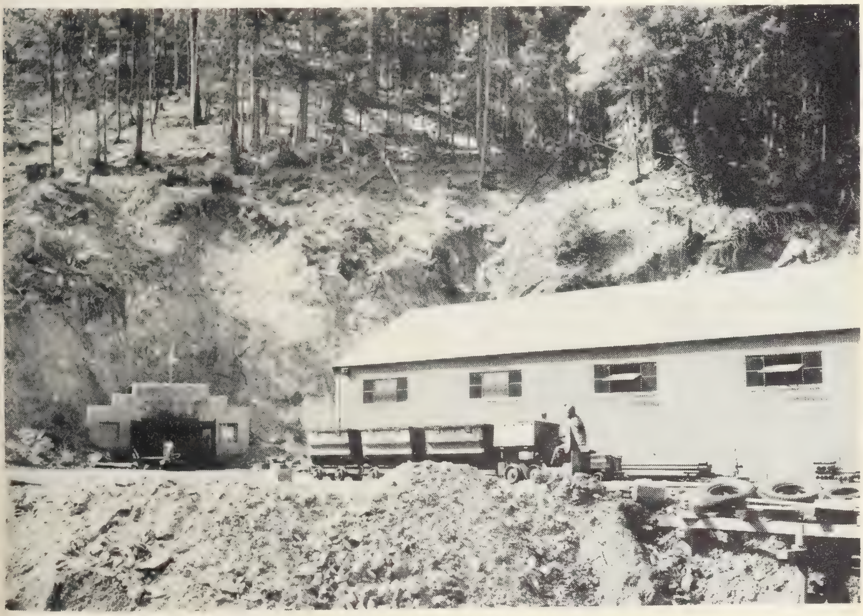


FIGURE 5. Ore train entering Cassidy level, Brush Creek mine; camera facing south.

ware & Supply Company, F. F. Cassidy, Nevada City. Leased by the Best Mines, Inc., P. O. Box 177, Downieville, California. Company officers are: Mrs. Irene Best, president, B. C. Austin, vice president, and L. L. Huelsdonk, secretary-treasurer and general manager. W. Reed is mine foreman and J. Folsom is mill foreman.

By 1875, an estimated $1,000,000 had been produced from workings of the old Brush Creek shaft (Ferguson and Gannett, 1932, p. 87). In 1922-23, the Ante-Up Mining Company drove the Brush Creek tunnel, which intersected the old shaft, sunk a winze, and produced a few thousand dollars worth of gold (Logan, 1929, p. 160). In 1927, the Kate Hardy Mining Company did some additional development work in the old workings.

The mine lay idle until reopening in 1944 by A. L. Merritt, who operated it until March 1950. The mine was then leased by the Best Mines Company. Until 1951, the mine was worked through the Merritt adit and the old Cassidy shaft. In 1951 the Cassidy adit, which is now the main haulage way for the mine, was started. The mine is active at the present time, and to date has a total production of nearly $4,000,000, half of which is based on a price of $20.67 per ounce (L. L. Huelsdonk, personal communication, 1954).

The quartz vein in the present workings ranges from 3 to 15 feet thick, strikes north, and dips west at an average of 42 degrees. The vein occurs near and along the contact of black slate of the Cape Horn formation to the west and serpentine to the east. In some places it lies largely within the slate, but in others serpentine forms the footwall and slate forms the hanging wall. Native gold occurs sporadically as high-grade concentrations in quartz and is associated with minor amounts of auriferous arsenopyrite, galena, and pyrite. One of the most recent high-grade ore discoveries was on the 125-foot level off the Golden Gate shaft. The ore shoots commonly are nearly vertical. A replacement mixture of carbonate and mariposite attains a thickness of up to 50 feet between the vein and the serpentine footwall. The gold averages 830 in fineness.

The main working entry of the Brush Creek mine at present is the 2,600-foot Cassidy adit which extends in a south to southwest direction. The first 1,300 feet of the adit is in serpentine while the remainder is in Cape Horn slate. Elevation of the adit portal is 3,158 feet. The Merritt Crosscut adit, 1,500 feet south of the Cassidy adit portal, and 171 feet higher in elevation, extends 600 feet west to the vein and is the other working entry. Three raises connect the Cassidy and Merritt levels from which intermediate drifts and stopes have been worked. Nearly all of the ore production since World War II has been from this portion of the mine.

During the summer and fall of 1954, a winze known as the Golden Gate shaft was sunk from the Cassidy adit 2,000 feet in from the portal. On the 125-foot level of this winze, a 60-foot southeast crosscut was driven to the vein and 30 feet of drifts driven on the vein to October 1954. Present production is from this level and from the Cassidy adit which is being extended.

Older workings of the Brush Creek mine which are not used at present include the 60-foot inclined Brush Creek shaft, the 2,200-foot Brush Creek adit which intersects the shaft, the 5,000-foot Extension adit, the 600-foot Ante-Up adit, and the 500-foot Peavine adit. The collar

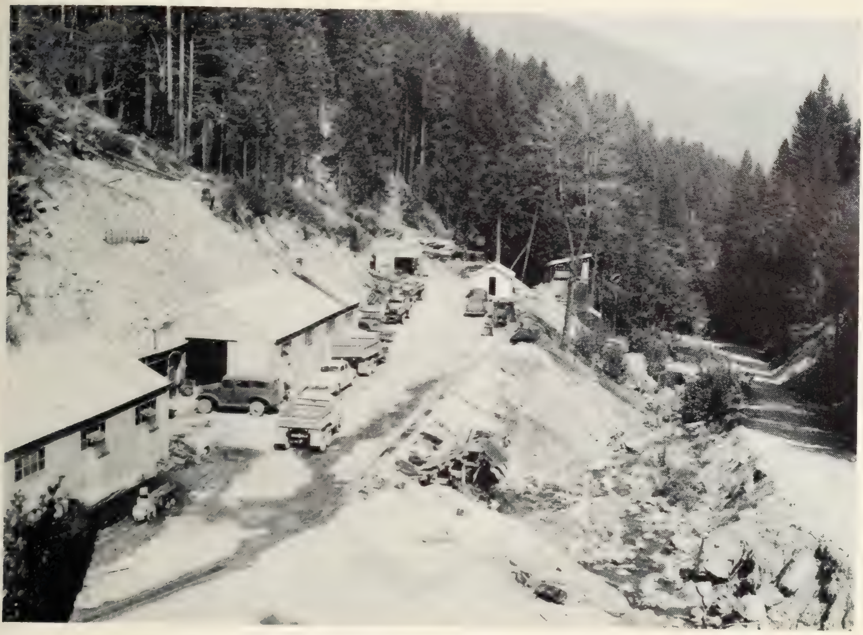


FIGURE 6. Mine yard at Cassidy adit, Brush Creek mine. Loading bins are shown at right. Camera facing north.

of the Brush Creek shaft is just south of the Mountain House saddle, 1½ miles south of the Cassidy adit portal.

Five stopers, which include three Ingersoll-Rand 48 and two Ingersoll-Rand 58 and two T-350 Sullivan drifters mounted on Joy jumbo arms are used for drilling. Ingersoll-Rand screw-on bits with tungsten inserts are used. The mine is equipped with two 500-cubic foot Ingersoll-Rand compressors. The mine workings are ventilated by a 350-cubic foot blower located on the Cassidy level. Two storage battery locomotives, a Mancha and a General Electric, are used for tramming the ore trains. Capacity of the ore cars used on the Cassidy level are two tons while those used on the Merritt level are one ton. An underground hoist in the Cassidy adit serves the Golden Gate shaft.

High-grade ore is hand sorted at the place where it occurs and is handled and milled separately. Milling ore and waste are trammed from the two adits and deposited into respective bins. The ore is trucked 5 miles to the mill, which is located at the Oxford mine, 1 mile north of Downieville.

About 30 tons of ore are treated at the mill each day. The millheads average $30.00 per ton in gold (L. L. Huelsdonk, personal communication, 1954). The mill consists of a primary jaw crusher, secondary ball mill, Miners Foundry jig, Huelsdonk table, Denver grinding pan, a Wemco Dorr-type thickener, Wemco rake classifier, and Denver sub-A flotation cells. The free gold is amalgamated, retorted and sold to the mint. The flotation concentrates are sold to the Empire Star mine in Grass Valley.

There are 22 men working at the mine and two men at the mill. The work schedule is a 6-day week, and generally one shift per day.

Gold Bluff Mine. Location: secs. 23 and 26, T. 20N., R. 10E. and secs. 2 and 3. T. 19N., R. 10E., M. D. M., 1½ miles north of Downieville on the Downie River. Ownership: Mrs. Irene Best, Downieville.

Originally worked in 1851, the Gold Bluff gold mine was active almost continuously until 1902 (MacBoyle, 1920, p. 10). The mine was again in operation during 1914-1916. In 1948, the Best Mines Inc. purchased the property and, in 1950, the mine was rehabilitated and several hundred feet of drifts and crosscuts were driven. Several hundred tons of ore were produced, largely from support pillars remaining in the old workings. The ore was treated at the Oxford mill. Except for occasional maintenance work, the mine is idle at the present time. Total production for the Gold Bluff mine is estimated to be $1,500,000 based on a gold price of $20.67 per ounce (L. L. Huelsdonk, personal communication, 1954).

Native gold and auriferous pyrite occur in two quartz veins, the Fault or Gold Bluff and Crescent veins. The Fault vein strikes N. 20° W., dips 70° northeast, and ranges from 3 to 5 feet wide. The Crescent vein averages 5 feet wide, strikes N. 60° E. and dips 45° northwest. The veins occur at or near the contact of metavolcanic rocks and slate. The metavolcanic rocks lie to the east.

The mine is developed by two adits, the No. 2 and C. L. or No. 4 adits which crosscut west to the veins. The C. L. or No. 4 adit, the portal of which is located on the Downie River, was the main haulage way. It extends 1400 feet west to the veins and from there, drifts extend north. A 500-foot north inclined winze was sunk from the No. 4 level about 200 feet north of the No. 4 adit. The No. 3 adit, which is 210 feet above the No. 4 adit, extends 1,050 feet west to the veins. A 600-foot south-west crosscut was driven on the No. 4 level southwest of the veins by the Best Mines Company in 1950.

At the present time there is no equipment on the mine property except for several storage sheds and cabins near the C. L. adit portal.

Gold Crown (Wonder) Mine. Location: sec. 3, T. 18N., R. 10E., and sec. 34, T. 19N., R. 10E., M. D. M., in Alleghany. Ownership: Gold Crown Mining Corporation, Alleghany.

The Gold Crown gold mine was first worked as the Wonder mine. By 1922, the Flynn Brothers, H. T. Bradbury, and the J. Walsh Estate had done considerable development work (Logan, 1922, p. 519) in the old upper tunnel workings. In the middle 1920's, the Sierra Wonder Company drove a lower tunnel to the serpentine contact. In the latter 1930's the Duke family operated the property as the Wonder gold mine and started a new upper tunnel above the Flynn and Bradbury workings and began sinking a shaft.

In 1944-45, the Wonder Mining Company deepened the Duke shaft to 67 feet. The property was idle until 1949-50 when the company was re-incorporated as the Gold Crown Mining Corporation. During this time the shaft was deepened and some work was done on the north 100-foot level and the 67-foot level south of the shaft.

Between July 1951 and July 1954, the Giles brothers, development contractors for Gold Crown Mining Corporation, continued development work on the 100-foot level and in the lower tunnel. Since 1952, all development work was confined to the lower tunnel. The mine is intermittently active at the present time.

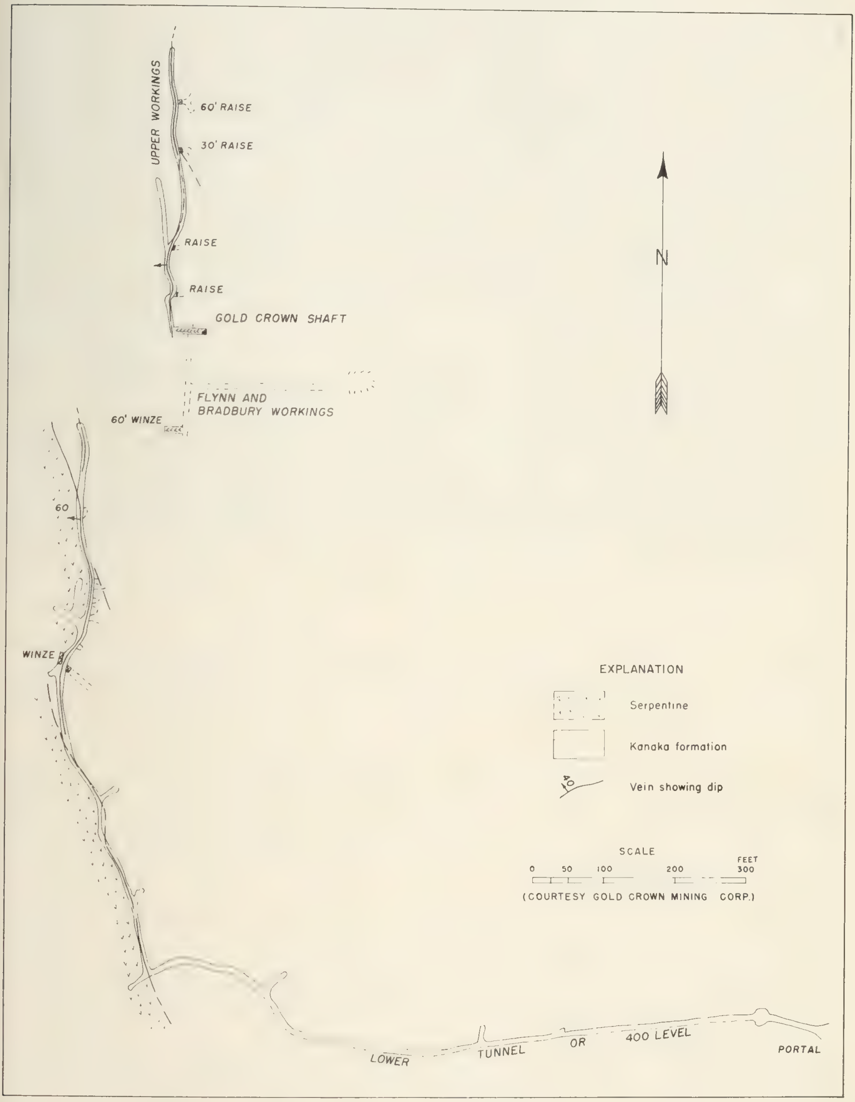

UPPER WORKINGS
60' RAISE
30' RAISE
RAISE
RAISE
GOLD CROWN SHAFT
FLYNN AND BRADBURY WORKINGS
60' WINZE
60
WINZE
LOWER TUNNEL OR 400 LEVEL
PORTAL
N
EXPLANATION
Serpentine
Kanaka formation
40
Vein showing dip
SCALE
0
50
100
200
FEET
300
(COURTESY GOLD CROWN MINING CORP.)

Figure 7. Underground workings of Gold Crown mine.

In the lower level, the vein was encountered by exploring the serpentine-Kanaka formation contact. This vein diverged from the serpentine-Kanaka formation contact at a small angle and pinched out against the serpentine. The vein was then followed about 300 feet to the north. The vein has a general strike of north, dips west, and ranges from a few inches to 4 feet in width. Some high-grade ore was found near the serpentine. County rock includes serpentine and interbedded slates and tuffs of the Kanaka formation.

Mine development work includes a 104-foot shaft, a south drift, crosscut and winze on the 67 level and 470 feet of drifting and two small raises on the north 100 level. Other development work consists of a 200-foot west crosscut to the vein and drifts north 100 feet and south 75 feet. A 60-foot winze was sunk on the vein in the south drift 60 feet from the crosscut (Logan, 1922, p. 519). These upper workings are not being used at the present time.

Present development work is in the main adit or lower tunnel, the portal of which is about 0.3 mile southeast of the shaft and about 520 feet lower in elevation than the collar of the shaft. The lower tunnel was crosscut 1,000 feet west to the serpentine-Kanaka formation contact. Then the development work continued along the contact 400 feet north where a west dipping, north-striking quartz vein was encountered. The vein has been drifted on for a distance of 300 feet and some stoping has been done. A winze is being sunk from the lower level on the vein near the serpentine. During the middle of 1954, the winze had been sunk to a depth of 6 feet.

Swedish-Atlas Copco drills are used for drilling rounds. A mucking machine is used to load ore into 1-ton side-dump ore cars. Milling-grade ore is stockpiled at the present time as there is no mill on the property.

In the middle or Hyland level, the main vein strikes N. 45° W., while in the lower level, the strike averages N. 40° W. Two branch veins diverge to the north in the lower level 500 feet in from the portal. Dip of the vein ranges from 30 to 70 degrees northeast; the dip of the vein in the vicinity of the No. 1 ore zone, however, averages less than 40 degrees.

The No. 2 ore zone is located just northwest of the adit in the upper level and near the end of the lower level. Recent production was obtained from the No. 1 ore zone in the Hyland level between 300 and 500 feet in from the crosscut adit. None of the levels are connected underground.

Country rock consists of highly sheared gabbro, tuff, and slate of the Kanaka formation. Serpentine is encountered in the hanging wall in the Hyland level about 600 feet in from the portal. The productive parts of the vein are associated with carbonate alteration of the wall rock. Native gold occurs sporadically in bunches and is nearly always associated with coarse arsenopyrite.

Light-weight Swedish-Atlas-Copco jackleg drills are used in mining. The ore is hand trammed to a storage bin near the portal from where it may be trucked to a mill. Surface equipment at the mine includes a 10-by-12-inch Gardner Denver compressor, boarding house, blacksmith shop, and storage sheds. Five men are employed at the mine.

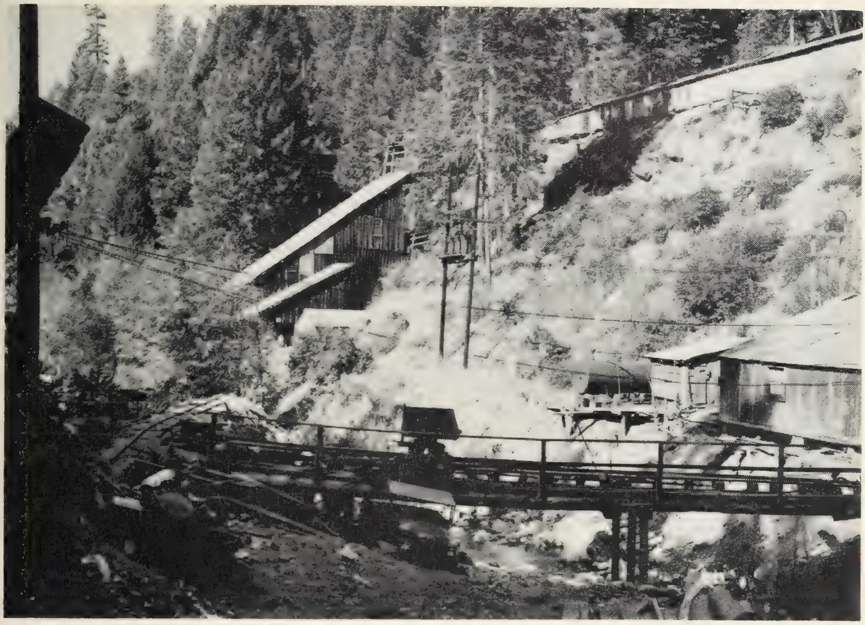


FIGURE 8. Kate Hardy mine and mill, from south side of Oregon Creek; camera facing west.

Kate Hardy Mine. Location: sec. 29 and 32, T. 19 N., R. 10 E., M. D. M., 2½ airline miles northeast of Alleghany. Ownership: H. E. Hawn, P. O. Box 748, Grass Valley, California.

The Kate Hardy mine was worked at intervals between 1860 and 1927. Between 1941 and 1953, the mine was leased and worked by the O'Donnell brothers. In April, 1953, H. E. Hawn purchased the mine from the Beggs Estate and some development work, mining and milling have been done since that time. Total gold production for the mine is approximately $547,000 (H. E. Hawn, personal communication, 1954).

The quartz vein, which occupies a reverse fault, has an average strike of N. 23° W. and dips 75°-80° southwest. The quartz vein ranges from a few inches to several feet in width, although a maximum width of 55 feet has been encountered. The vein lies in the Cape Horn slates and cuts the slate at a small angle in strike and dip (Ferguson and Gannett, 1932, p. 90). Dikes of gabbro and serpentine cut the vein irregularly in places. Considerable slate has been replaced by carbonate close to and within the vein. Mariposite is erratic in distribution and is not necessarily confined to the vicinity of the serpentine. Arsenopyrite, pyrite and galena are present.

The principal workings are south of Oregon Creek and consist of several adits, the lowest a few feet above the creek level (No. 4 tunnel) and the highest 250 feet above the creek. A 75° inclined winze was sunk from the No. 4 level about 300 feet in from the portal. Three levels branch off the winze north and south, the principal level being the No. 1 level which is about 100 feet below the No. 4 level. The No. 1 level extends to the north about 1,000 feet. Most of the production previous to 1927 came from the south workings.

Since 1940 most of the gold production has been from the workings north of Oregon Creek. The north workings include lower and upper drift adits. The lower adit is 66 feet lower in elevation than the upper adit and was driven a distance of 1,350 feet along the vein. A raise, which was driven about 500 feet in from the lower adit portal, extends to a height of about 44 feet. From the top of the raise, an intermediate drift was driven 35 feet south. At this point a raise was driven about 22 feet to connect into the upper adit. The upper adit was started in 1951.

During 1954, the upper adit was extended to its present 600-foot length, the two north adits were connected underground, and a raise off the upper adit was driven to a height of about 70 feet. At the present time, mining and reopening work is underway on the No. 1 level below the north workings. An Ingersoll-Rand 48 stoper is used for drilling and the ore is hand-trammed to the mill, which is located immediately west of the north adit portal.

Small tonnages of ore are milled at the present time. The mill, which has a rated capacity of 40 tons per day, is equipped with a 3 x 4-foot ball mill (which produces a minus 20-mesh product), Miners Foundry jig, Dorr rake classifier, Knudsen Bowl, and Wilfley tables. The free gold is amalgamated, retorted, and sold to the U. S. Mint in San Francisco. Concentrates are shipped to the Empire-Star mill in Grass Valley. Three men are employed at the mine.

Irelan (Ireland) Mine. Location: secs. 10 and 11, T. 18 N., R. 10 E., M. D. M., 2 airline miles south of Alleghany on the south side of Lafayette Ridge. Ownership: A partnership known as the Yuba-Irelan Mines, Ltd., Joseph Harris, manager, Alleghany.

The Irelan mine is the only active gold mine in the Lafayette Ridge area at the present time. The mine was originally worked around 1860 and was active at intervals until 1924 (Ferguson and Gannett, 1932, p. 127). During the 1930's the principal workings were extended, but there was little ore production. In 1936, a fire destroyed most of the surface plant. In 1949, George Hyland purchased the mine and developed the Hyland level. Since 1953, the mine has been operated by Yuba-Irelan Mines, Ltd. The lower level is being rehabilitated while some ore has been produced from stopes in the Hyland level. This ore was milled at the Red Star mill in Alleghany during July and August, 1954. The mine is under development at the present time. Total estimated production for the Irelan mine is slightly more than $500,000 based on a gold price of $35 per ounce (Joseph Harris, personal communication, 1954).

There are two quartz veins, the east and west on the property; they trend northwest and dip moderately to steeply northeast. Virtually all of the mine production has been from the east or main vein. In the upper level or Waldron level, the main vein has an average strike of N. 60° W., but changes sharply to N. 30° W. about 500 feet in from the crosscut adit and continues on this course for 500 feet. At this point the main vein bends toward its original direction again. The change in direction corresponds to a projected junction with the west vein (Ferguson and Gannett, 1932, p. 128) and the greatest amount of production has been from this segment of the vein which is known as the No. 1 ore zone. Much of the vein in the vicinity of the No. 1 ore zone has been stoped out.

Mugwump (Young America) Mine. Location: secs. 28 and 33, T. 19 N., R. 10 E., M. D. M., a quarter of a mile southwest of Forest. Ownership: Cecil Vivian, Forest.

Originally known as the Young America mine, the Mugwump mine was first worked in 1852 (Ferguson and Gannett, 1932, p. 93). It is a combination lode and drift mine, but the greatest amount of development work has been in the buried gravel channel with the majority of the total mine production being placer gold. The quartz vein was encountered in bedrock when the buried channel was originally developed. The property was active from 1892 to 1896 and again from 1916 to 1928 (Logan, 1929, p. 195). Since November, 1953, the present owner has been developing the mine through a new adit. Estimated lode production is about $5,000 at a gold price of $20.67 per ounce (Ferguson and Gannett, 1932, p. 93).

The vein occupies a fault zone in slate and green schist of the Kanaka formation. The vein strikes N. 35° W., dips 60 to 72 degrees southwest, and measures as much as 3 feet in width. Small but high-grade ore shoots composed of native gold associated with arsenopyrite were found in the winze just below the adit level and from an area 850 feet to the southeast near the end of the lower level. In both places where high-grade ore was found, the dip of the vein was flatter than usual (Ferguson and Gannett, 1932, p. 94). A north-striking vein some 1,300 feet to the northwest of the main vein and exposed about 100 feet in from the adit portal may be a faulted segment of the main vein.

The older workings are developed by a southeast-extending adit, the portal of which is on Oregon Creek. The vein is encountered 1,400 feet in from the portal. An inclined winze extends 125 feet to the lower level from this point. The main adit level drifts along the vein and then continues on to the southwest along the buried gravel channel. The lower or winze level drifts along the vein for about 850 feet southeast from the winze.

The new adit, the portal of which is about 600 feet southwest of the Mugwump portal, extends 800 feet southeast. It is entirely in green schist of the Kanaka formation. A raise has been driven to the gravel channel 600 feet in from the portal and a washing plant is being installed. The adit is continuing to be developed to the southeast toward the vein. Six men including Mr. Vivian work at the mine.

Oriental Mine. Location: sec. 4, T. 18 N., R. 10 E., and sec. 33, T. 19 N., R. 10 E., M. D. M., 1 mile southwest of Alleghany. Ownership: Drescher Estate, Financial Building, Sacramento, and Mrs. W. E. Kliensorge, 2161 Hyde Street, San Francisco; leased by The Dickey Exploration Company, Alleghany, Donald R. Dickey, general manager.

More than $2,000,000 was produced from the Oriental gold mine prior to 1890 (Ferguson and Gannett, 1932, p. 99). The mine was active in 1900 (Lindgren, 1900, p. 8) and again from 1915 to 1917 (MacBoyle, 1920, p. 108). A few thousand tons of low-grade ore was produced during the period 1924 to 1926 (Logan, 1929, p. 168). From the latter 1930's to 1942 the mine was active. The Dickey Exploration Company reopened the mine in 1946 and at the present time, production is ap-

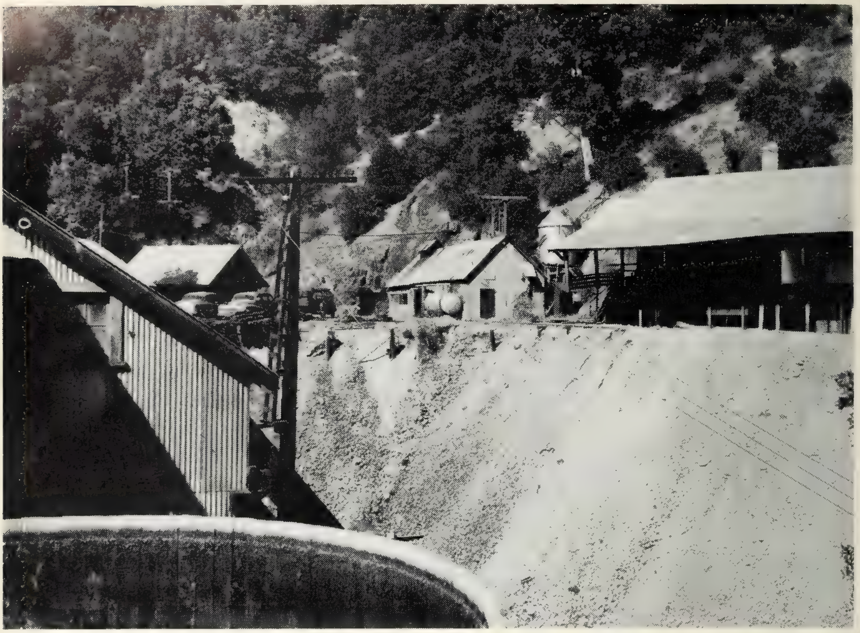


FIGURE 9. Oriental mine yard; Oriental adit in center of photo, camera facing north.

proximately 30 tons of ore per day (Donald R. Dickey, personal communication, 1954). Estimated total production for the mine is $4,250,000 figured at a gold price of $35 per ounce.

The Oriental vein lies in the plane of a reverse fault that has a displacement ranging from 120 to 200 feet (Ferguson and Gannett, 1932, p. 99). The strike of the vein is west in the eastern portion of the mine. As the vein approaches the serpentine to the west the strike swings to N. 65° W. Dip ranges from 28 to 50 degrees north and northeast, the flatter dips being near the serpentine. Width of the vein ranges from thin stringers to 20 feet. Vein branching is common throughout the workings and near the serpentine, the vein branches into a complex series of small veins and stringers which grade into a replacement mixture of carbonate and mariposite.

The vein has been most productive near the serpentine-gabbro contact in the upper workings and in an area between the 400-foot level and the surface. In this latter area, the vein splits into several branches, and stopes following these branches from the 400-foot level to the surface yielded over $1,500,000 (Ferguson and Gannett, 1932, p. 100). The high-grade ore is nearly always associated with coarse crystalline arsenopyrite.

At the 8th level, a junction is made between the Oriental and Alta veins. The Alta vein is a flatter vein in the footwall of the Oriental vein. The strike is roughly parrallel to that of the Oriental vein and the dip is gentle to the north (Averill, 1942, p. 33).

A new vein was discovered in 1952, in the hanging wall, that is generally parallel to the main Oriental vein. Recent production has been concentrated close to the junction of this vein with the serpentine.

Schistose gabbro is the principal wall rock of the veins in the Oriental mine. In the western portion of the workings, serpentine forms the footwall. A mass of granite forms the wall rock of the vein extending from the 9th level to below the 19th level. On the 13th level, the granite extends for a distance of 350 feet along the vein. The Oriental mine is the only mine in the Alleghany area where the wall rock is granite. Other rocks in the general area include diorite, quartz diorite, and quartzite.

The mine is developed by a 3,800-foot crosscut known as the Oriental adit or 13th level at an elevation of 3,620 feet. This adit, which was driven N. 30° E., is the main haulage way for the mine. Near the end of the adit, drifts extend several hundred feet east and 750 feet west-northwest along the Oriental vein. An old inclined shaft, the collar

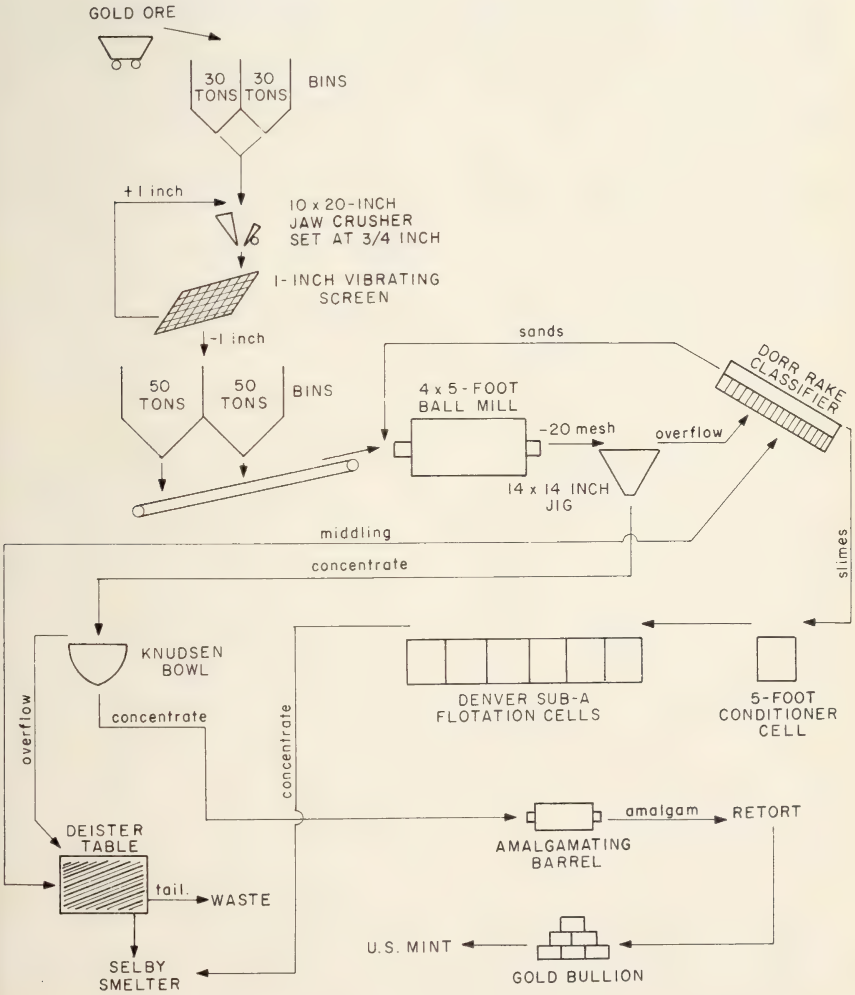

GOLD ORE
30 TONS
30 TONS
BINS
+1 inch
10 x 20-INCH JAW CRUSHER SET AT 3/4 INCH
1-INCH VIBRATING SCREEN
-1 inch
50 TONS
50 TONS
BINS
sands
DORR RAKE CLASSIFIER
4 x 5-FOOT BALL MILL
-20 mesh
overflow
14 x 14 INCH JIG
middling
concentrate
slimes
KNUDSEN BOWL
overflow
concentrate
concentrate
DENVER SUB-A FLOTATION CELLS
5-FOOT CONDITIONER CELL
DEISTER TABLE
amalgam
RETORT
AMALGAMATING BARREL
tail.
WASTE
U.S. MINT
GOLD BULLION
SELBY SMELTER

FIGURE 10. Oriental mill flowsheet.

of which is 780 feet above the adit portal, was sunk on the vein. Ten levels ranging from 30 to 100 feet apart in elevation extend east and west along the vein from the shaft, the most extensive being the 4th level which is about 600 feet long. The shaft bottoms on the 12th level and a raise driven from the 13th level to the 12th level connects the shaft with the lower workings.

Since World War II, a 600-foot inclined winze has been sunk from the northwest end of the 13th level to a new level known as the 19th level. Drifts and crosscuts extend both northwest and southwest from this level. Most of the post World War II production has been from stopes between the 19th and 13th levels northwest of the winze and from the newly discovered hanging wall vein.

Ore is hoisted up the winze, and trammed by a Mancha electric locomotive along the 13th level to the mill. Lightweight Swedish Atlas Copco drills and mucking machines are used in mining.

Milling-grade ore is treated by crushing, grinding, jigging, and flotation. High-grade is treated separately by grinding and amalgamation.

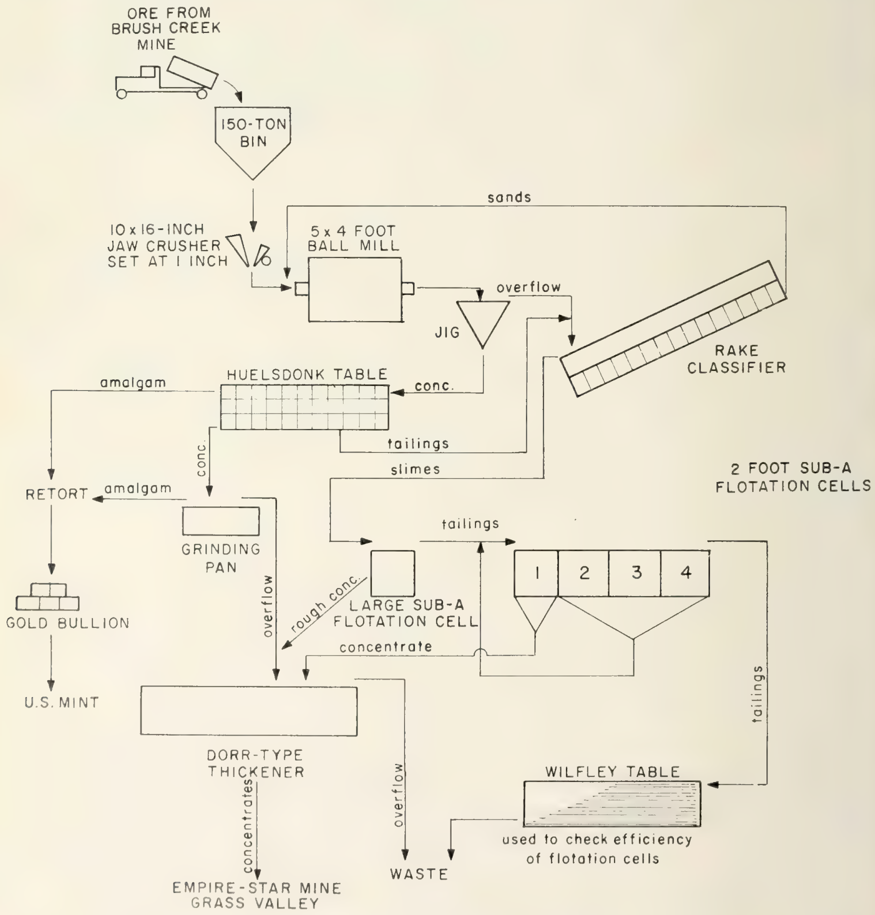

ORE FROM BRUSH CREEK MINE
150-TON BIN
10 x 16-INCH JAW CRUSHER SET AT 1 INCH
sands
5 x 4 FOOT BALL MILL
overflow
JIG
RAKE CLASSIFIER
HUELSDONK TABLE
amalgam
conc.
tailings
slimes
2 FOOT SUB-A FLOTATION CELLS
RETORT
amalgam
conc.
GRINDING PAN
tailings
1
2
3
4
GOLD BULLION
overflow
rough conc.
LARGE SUB-A FLOTATION CELL
concentrate
U.S. MINT
tailings
DORR-TYPE THICKENER
WILFLEY TABLE
concentrates
overflow
used to check efficiency of flotation cells
WASTE
EMPIRE-STAR MINE GRASS VALLEY

FIGURE 11. Oxford mill flowsheet.

Mill recovery ranges from 85 to 90 percent (Donald R. Dickey, personal communication, 1954). Mill capacity is rated 75 tons per day although 30 tons are milled per day at the present time. Eight men work in the mine and three men in the mill.

Oxford Mine. Location: secs. 22, 23, 26, 27, T. 20 N., R. 10 E., M. D. M., one mile north of Downieville. Ownership: Oxford Quartz Mining Company, Downieville.

The Oxford gold mine has been intermittently active since the early 1890's. Between 1945 and 1948 the Best Mines Company leased the property, during which time development work including some diamond drilling was done. The mine has been idle since 1948. (L. L. Huelsdonk, personal communication, 1954).

The principal vein strikes north, dips 72° east, and ranges in width from 2 to 7 feet. Country rocks consist of slate of the Calaveras group (Carboniferous in part). A body of serpentine was encountered in the Oxford adit about 50 feet west of the vein.

The Oxford adit (El. 3437 feet) is a west crosscut which extends through slate for a distance of 657 feet to the vein. At the vein, a drift extends for about 2000 feet to the north. The Snyder No. 2 adit is 493 feet above and about 1700 feet north of the Oxford level. The Snyder No. 2 level is a west crosscut extending through slate to the serpentine contact for 1100 feet. A 600-foot drift branches to the north from this crosscut.

The Snyder No. 1 portal is 183 feet above and 500 feet northwest of the Snyder No. 2 portal. The Snyder No. 1 adit crosscuts to the west for 50 feet. The end of this level is connected to the Snyder No. 2 level by a raise.

Although the mine is idle the mill on the property is leased by the Best Mines Company to treat ore from the Brush Creek mine.

Red Star (Osceola, Yellow Jacket). Location: sec. 34, T. 19N., R. 10E., M. D. M., 1 mile northwest of Alleghany. Ownership: Tightner Mines Company, 58 Sutter Street, San Francisco, California.

This property has been operated intermittently since the early days of the district. The property is a consolidation of two mines, the Osceola on the east and the Red Star on the west. The Red Star mine is part of the original property of the Tightner Mines Company, which was consolidated with the Tightner workings in 1911 (Robert McCulloch, personal communication, 1955). It was active from this date until 1925. During the 1930's the Osceola portion of the property was worked. The first 1,500 feet of the working entry to the Red Star mine is on the Osceola claim.

From 1942 until early 1954, the mine was leased and operated by the Yellow Jacket Consolidated Mines, Ltd. Late in 1954 it was subleased for a short time by a partnership consisting of C. J. Ayres, D. B. Morton, J. Bach, and H. J. Adams. The mine is idle at the present time.

Prior to 1942 two veins were developed on the property; the Red Star and Osceola. Both veins trend northwest and dip moderately to steeply northeast. The Red Star vein lies approximately 1,200 feet west of the Osceola vein. Since 1942, a new vein has been developed

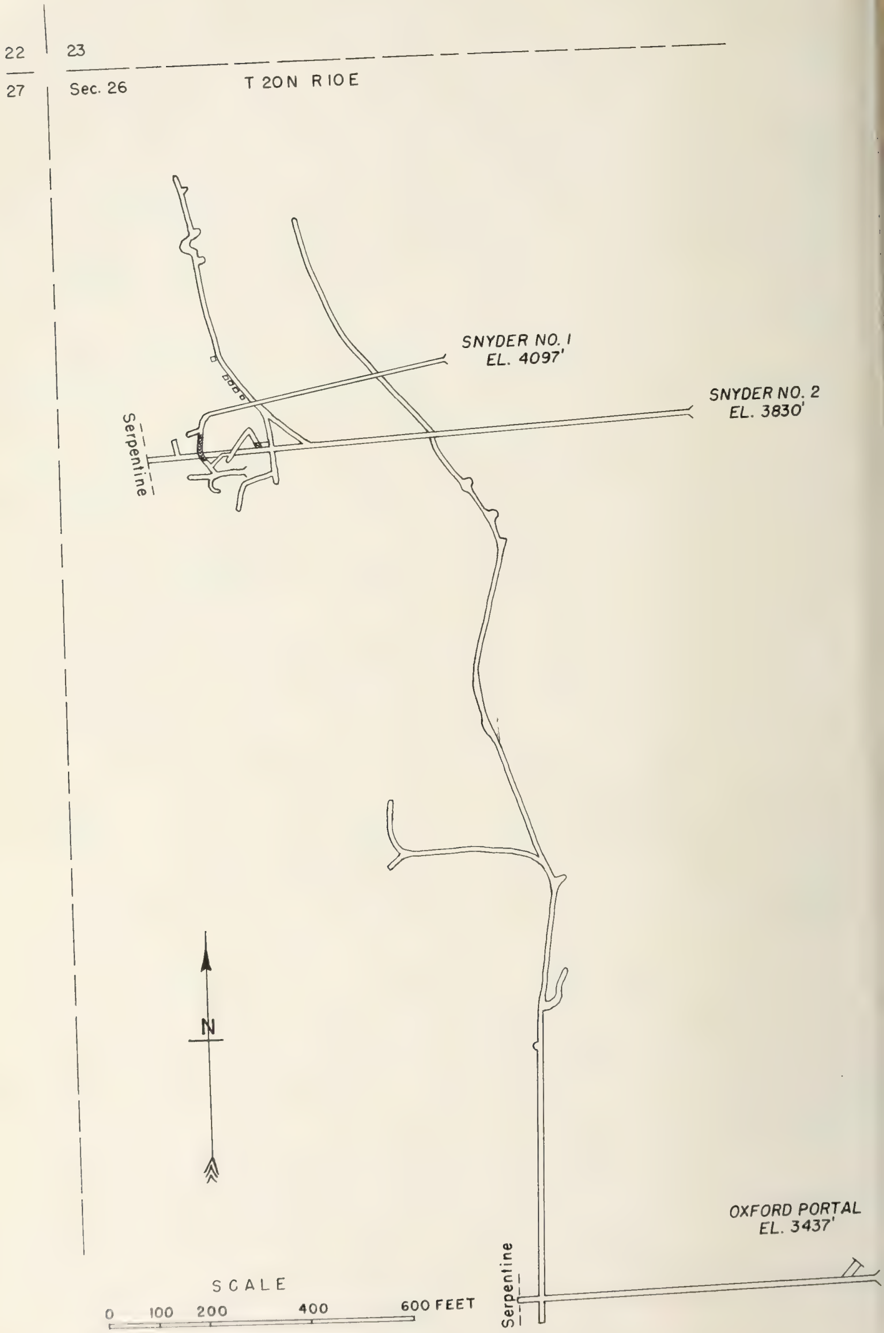

22
23
27
Sec. 26
T 20N R10E
SNYDER NO. 1
EL. 4097'
SNYDER NO. 2
EL. 3830'
Serpentine
N
OXFORD PORTAL
EL. 3437'
Serpentine
SCALE
0
100
200
400
600 FEET

FIGURE 12. Underground workings of Oxford mine.

below the 350 level of the new winze in the Red Star workings. All veins occur in amphibolite schist of the Tightner formation.

The Osceola vein strikes N. 42° W. and dips 50°-60° northeast for the first 400 feet in from the adit portal and then the strike changes to N. 66° W. and dip to 75°-80° northeast (Ferguson and Gannett, 1932, p. 115). Much of the production from this vein was from near the adit portal where a footwall branch extends to the southeast. A small body of serpentine lies about 100 feet west of this junction. Arsenopyrite is associated with the high-grade ore shoots.

The new vein in the Red Star workings has been the source of all of the production since 1942. It has a north to northwest strike, dips 30 to 45 degrees east, and ranges from 5 to 15 feet in width. The production was largely from stopes located between the 500-foot and 600-foot levels south of the winze.

The mine is developed by a 3,000-foot adit. For the first 1,500 feet beyond the portal, the adit drifts along the Osceola vein in the Osceola claim. The adit then crosscuts 1,200 feet west to intersect the Tightner fault. Three-hundred feet east of the fault a 600-foot inclined winze was sunk to intersect the projected extension of the 16-to-One vein which is believed to extend into this property (Robert McCulloch, personal communication, 1955). The shaft intersected the new or possible extension of the 16-to-One vein on the 500-foot level, and also levels have been run at 350 and 600 feet. The 500-foot level is the most extensively developed level on this new vein. The last work done, which was late in 1954, was on the 600-foot level where the north drift was extended 25 feet, and a winze was started near the 600 station. When in operation, ore was hand-trammed to the winze, hoisted, and then hauled by a storage battery locomotive to the mill.

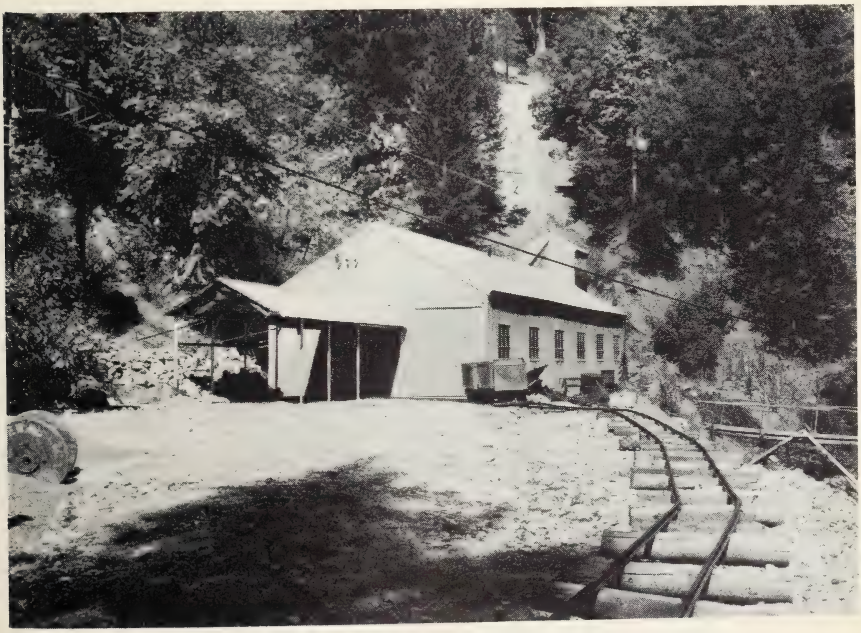


FIGURE 13. Red Star mine and mill; camera facing north.

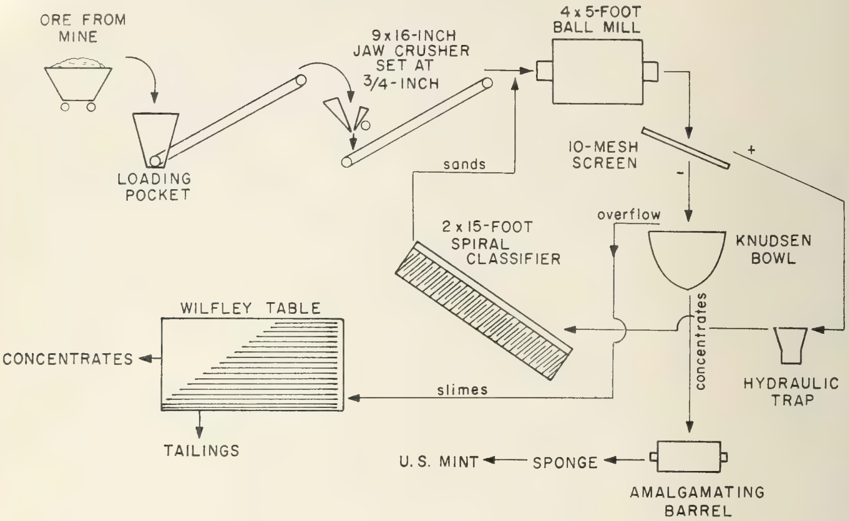

ORE FROM MINE
LOADING POCKET
9 x 16-INCH JAW CRUSHER SET AT 3/4-INCH
4 x 5-FOOT BALL MILL
10-MESH SCREEN
+
-
sands
overflow
2 x 15-FOOT SPIRAL CLASSIFIER
KNUDSEN BOWL
concentrates
HYDRAULIC TRAP
WILFLEY TABLE
CONCENTRATES
slimes
TAILINGS
U. S. MINT
SPONGE
AMALGAMATING BARREL

FIGURE 14. Red Star mill flowsheet.

The mill, which is located immediately northeast of the adit portal, was completed in April, 1953. Ore from the mine was deposited in a loading pocket and then belt-conveyed to the mill. At the mill, the ore was crushed, finely ground, sent to a 10-mesh screen, Knudsen Bowl, hydraulic trap, spiral classifier, and Wilfley table. Sponge gold was sold to the U. S. Mint in San Francisco. Mill capacity is 50 tons; however, when in operation, about 20 tons of ore per day were treated (C. J. Ayres, personal communication, 1955). Seven men worked at the mine and mill.

Sixteen-to-One Mine. Location: Secs. 3, 4, T. 18N., R. 10E., and sec. 34, T. 19N., R. 10E., M. D. M., in Alleghany. Ownership: Original Sixteen-to-One mine, Inc., 235 Montgomery Street, Room 1611, San Francisco 4, California. C. A. Bennett is superintendent, Willard Van Doren, mine foreman, J. B. Hunley, mill foreman, Wilford Hart, engineer.

The Sixteen-to-One property was located in 1896 and has since acquired claims which were formerly held by the Twenty-one and Tightner mines. The mine, which is the best known and most productive in the Alleghany area, has been continuously active since 1908. It is credited with a total gold production in excess of 730,000 fine ounces (Cooke, 1947, p. 212). Virtually all of the gold production has been from extremely rich ore shoots. Single shoots of ore in the Sixteen-to-One vein have yielded from $200,000 to as much as $1,000,000 in gold (Averill, 1942, p. 44).

The Sixteen-to-One vein occupies a reverse fault on which the amount of movement has been 300 to 900 feet (Ferguson and Gannett, 1932, p. 107). In the southern part of the mine the vein has a general strike of N. 30° W., but in the Tightner workings to the north its strike is essentially north. Although the dip varies greatly, from less than 20

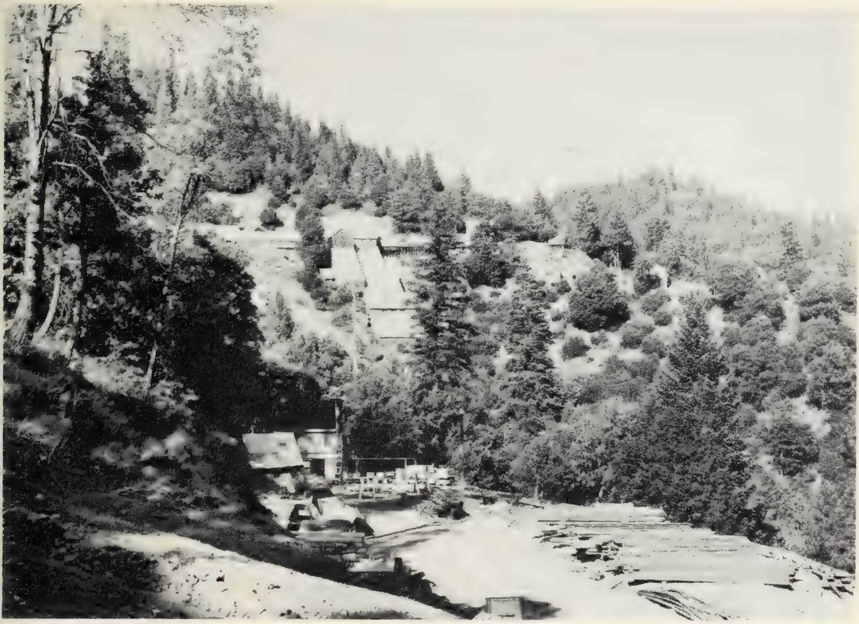


FIGURE 15. Gold Crown mine yard (foreground); Sixteen-to-One mine and mill (background); camera facing east.

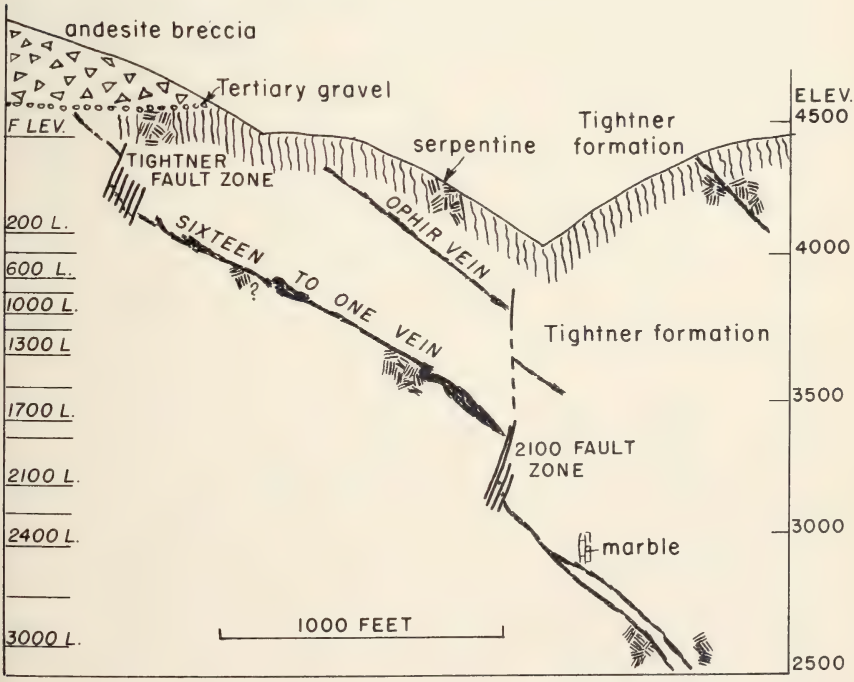

andesite breccia
Tertiary gravel
F LEV.
TIGHTNER FAULT ZONE
serpentine
Tightner formation
OPHIR VEIN
SIXTEEN TO ONE VEIN
?
Tightner formation
2100 FAULT ZONE
marble
1000 FEET
200 L.
600 L.
1000 L.
1300 L
1700 L.
2100 L.
2400 L.
3000 L.
ELEV.
4500
4000
3500
3000
2500

FIGURE 16. Generalized cross-section of Sixteen-to-One vein, Sixteen-to-One mine. (Modified after Cooke, 1947, p. 215.)

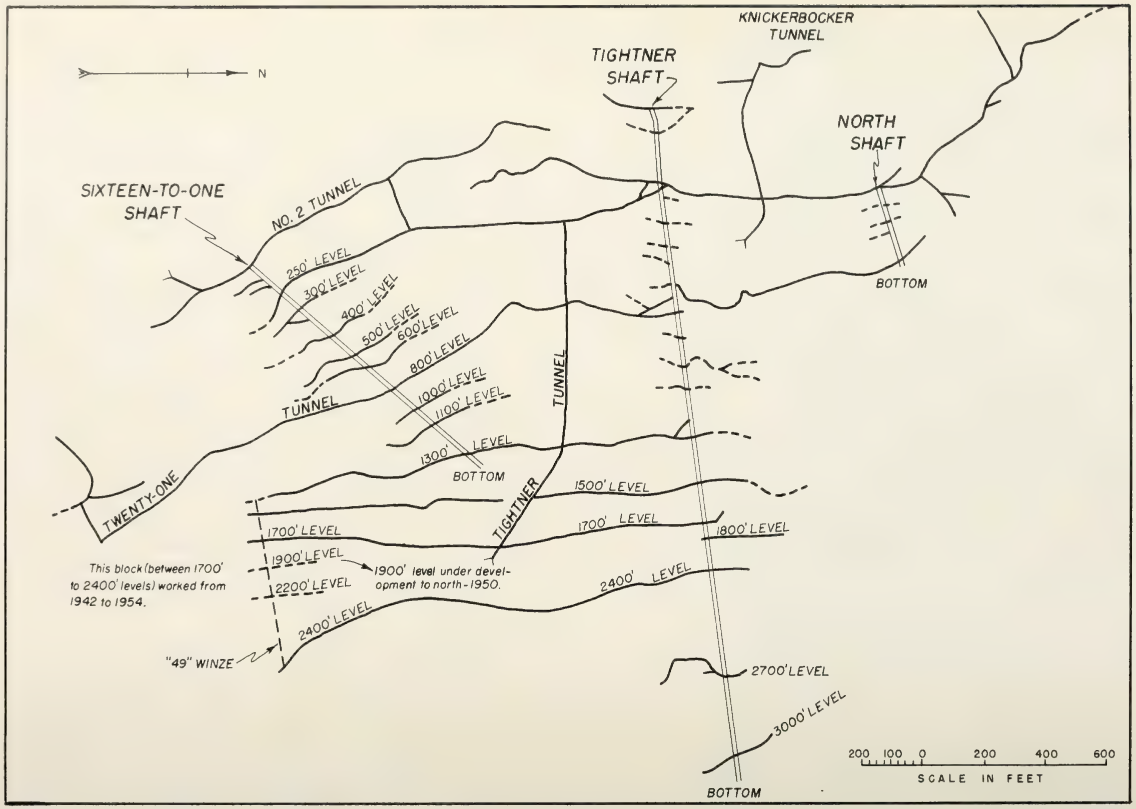

N
KNICKERBOCKER TUNNEL
TIGHTNER SHAFT
NORTH SHAFT
SIXTEEN-TO-ONE SHAFT
NO. 2 TUNNEL
250' LEVEL
300' LEVEL
400' LEVEL
500' LEVEL
600' LEVEL
800' LEVEL
1000' LEVEL
1100' LEVEL
TUNNEL
TUNNEL
1300' LEVEL
BOTTOM
BOTTOM
TWENTY-ONE
TIGHTNER
1500' LEVEL
1700' LEVEL
1700' LEVEL
1800' LEVEL
1900' LEVEL
1900' level under development to north-1950.
2200' LEVEL
2400' LEVEL
2400' LEVEL
This block (between 1700' to 2400' levels) worked from 1942 to 1954.
"49" WINZE
2700' LEVEL
3000' LEVEL
BOTTOM
200 100 0 200 400 600
SCALE IN FEET

FIGURE 17. Underground workings of Sixteen-to-One mine.

to 60 degrees northeast, the dip of the vein in the most productive parts of the mine ranges between 25 to 30 degrees.

The width of the vein is as much as 50 feet in places, but is usually 5 to 15 feet. The east-dipping Sixteen-to-One vein is cut by two groups of faults, which for the most part dip steeply to the west and have an average strike of N. 24° W. The upper group of faults, known as the Tightner fault zone, cuts the vein in the area between the two shafts between the No. 2 level and the 300-foot level. The lower group of faults, known as the 2100-fault zone, cut the vein between the 1800-foot and 2100-foot levels.

Hornblende schist of the Tightner formation comprises most of the country rock, although rocks of the Kanaka formation are found in the upper levels. Two dikes of serpentine cut the Tightner formation and are faulted by the vein.

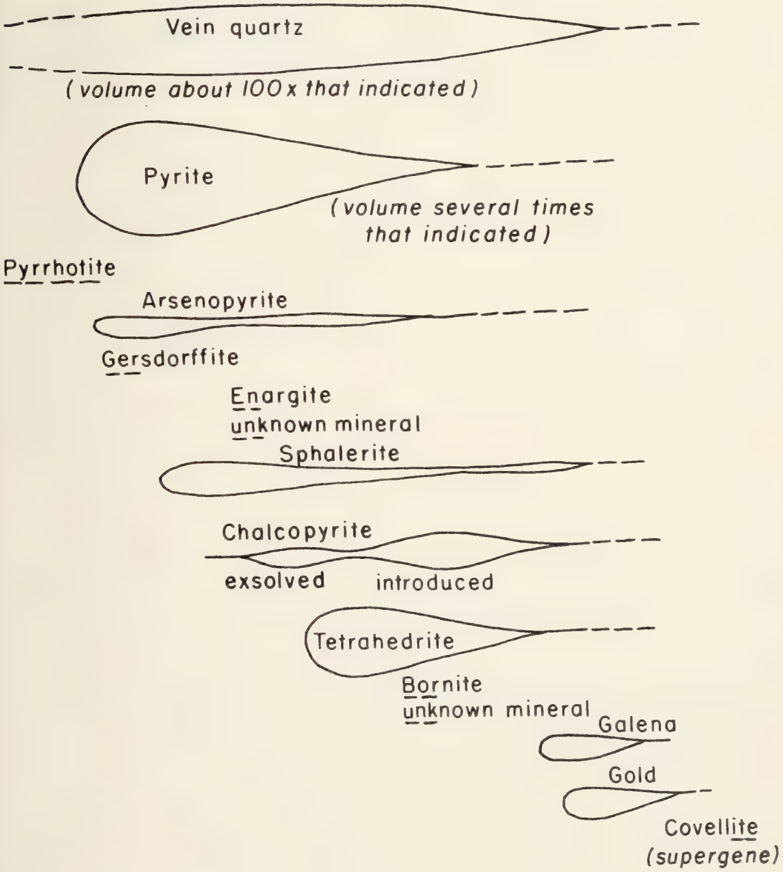

Vein quartz
(volume about 100x that indicated)
Pyrite
(volume several times that indicated)
Pyrrhotite
Arsenopyrite
Gersdorffite
Enargite
unknown mineral
Sphalerite
Chalcopyrite
exsolved
introduced
Tetrahedrite
Bornite
unknown mineral
Galena
Gold
Covellite
(supergene)

FIGURE 18. Sequence of mineral deposition in the Sixteen-to-One vein, Sixteen-to-One mine. (After Cooke, 1947, p. 232.)

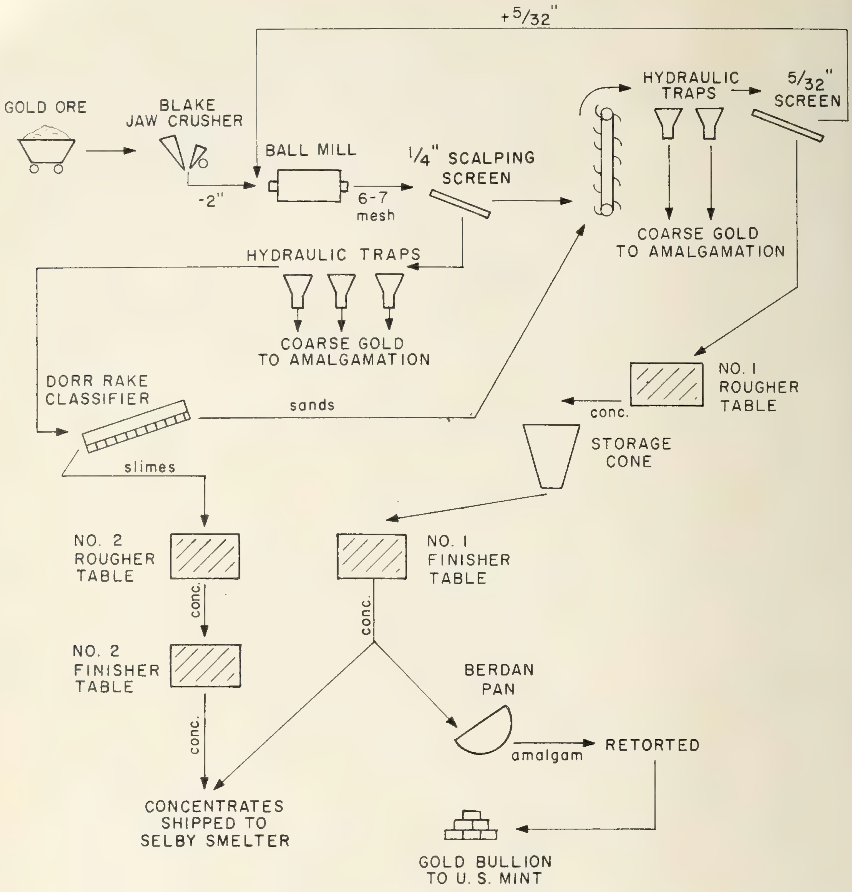

+5/32"
GOLD ORE
BLAKE JAW CRUSHER
-2"
BALL MILL
6-7 mesh
1/4" SCALPING SCREEN
HYDRAULIC TRAPS
5/32" SCREEN
COARSE GOLD TO AMALGAMATION
HYDRAULIC TRAPS
COARSE GOLD TO AMALGAMATION
DORR RAKE CLASSIFIER
sands
NO. 1 ROUGHER TABLE
conc.
STORAGE CONE
slimes
NO. 2 ROUGHER TABLE
NO. 1 FINISHER TABLE
conc.
conc.
NO. 2 FINISHER TABLE
BERDAN PAN
amalgam
RETORTED
conc.
CONCENTRATES SHIPPED TO SELBY SMELTER
GOLD BULLION TO U. S. MINT

FIGURE 19. Sixteen-to-One mill flowsheet.

The tenor of the veins is too low for profitable mining and consequently, the veins must be selectively mined so that a higher percentage of high-grade ore is mined than would be in random mining of the vein. Since no reliable criterion has yet been found to determine the position of high-grade shoots in advance of development work, the shoots are discovered by cutting the more favorable portions of the vein into small blocks by means of a large amount of development work.

A winze, known as the Sixteen-to-One shaft, is the main working entry to the mine at the present time. This winze extends from the No. 2 tunnel down to the 1,300-foot level. From the 1,300-foot level the 49 winze extends down to the 2,400-foot level. Since World War II, production has been from the vicinity of the 49 winze below the 1,700 level. The lowest level now worked is the 2,400 level. The ore is hoisted up the 49 winze to the 1,300 level where it is trammed northward to the Sixteen-to-One shaft. The ore is then hoisted up the Sixteen-to-One shaft to the No. 2 tunnel and trammed by airtrammer to the mill. The Tightner shaft collared on the 250 level and extending to the 3,000 level was at one time the main working shaft for the mine and is still maintained for pumping, servicing and ventilation.

Open timbered stopes utilizing slusher scrapers are typical of the Sixteen-to-One Mine. Mine waste is used for filling old stopes. Drilling is done by Ingersoll-Rand R-58 stopers. In drilling drift and crosscut headings, the stopers are mounted on air bars. Two changes of steel equipped with throw-away bits are used to drill 6-foot holes. Compressed air and electric slushers and two pneumatic mucking machines handle the broken ore. Five storage battery locomotives haul 1-ton side-dump ore cars. A compressed air trammer is used for haulage on the surface.

At the mill the ore is crushed by a primary jaw crusher and secondary ball mill, classified by a Dorr rake classifier, and the fines are concentrated on Deister tables. High-grade ore, which amounts to approximately 50 percent of the total production, is handled and milled separately. The free gold concentrate from the mill, which amounts to approximately 45 percent of the total production, is amalgamated and retorted. The sulfide concentrates are shipped to the Selby smelter.

The mine and mill operate 6 days per week and one and 1½ shifts per day, respectively. Thirty-six men are employed at the mine and mill.

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LIST OF LODE GOLD MINES IN THE ALLEGHANY-DOWNIEVILLE AREA THAT HAVE BEEN ACTIVE SINCE 1942

The list of lode gold mines and prospects is arranged alphabetically. The number in the first column refers to the location on the map in pocket. The names and numbers in parentheses in the last column refer to the accompanying bibliography. The first number after the author's name is the year of publication, and is separated from the page reference by a colon. Other references are separated by semicolons. The term ''herein'' refers to a description in this paper.

LIST OF LODE GOLD MINES IN THE ALLEGHANY-DOWNIEVILLE AREA THAT HAVE BEEN ACTIVE SINCE 1942

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
1	Brush Creek	Alpha Hardware & Supply Co., F. F. Cassidy, Nevada City	17, 18, 19	19N	10E	MD	(Lindgren 00:8; Ferguson 15:182; Mac Boyle 20:79; Logan 22:502; Logan 24:17; Logan 29:160; Ferguson and Gannett 32:26, 87-89; Averill 42:21; Bowen and Crippen 48:78; Averill 49:122; O'Brien 51:371; herein).
--	Colorado						See Yellow Jacket
2	El Dorado	George S. Fessler Estate, Jane A. Morris, 806 E. Calif. Ave., Sunnyvale	34, 35	19N	10E	MD	Surface clean up and some retimbering of the adit is being done by Roland De Grio. (Preston 92:407; Crawford 96:372; Ferguson 15:174; Mac Boyle 20: 85-86; Logan 21:474; Logan 22:503-505; Ferguson and Gannett 32:118-119; Logan 35:3).
3	Eureka	O. P. Bixby et al., 537 W. Grand Ave., Oakland, Calif.	29, 32	19N	10E	MD	A small quantity of gold was produced by Maurice Derrnan in 1946. Leased by C. J. Ayers in 1949. At present, a small amount of rehabilitation work is being done by Mr. Bixby. (Ferguson and Gannett 32:55, 92).
4	Gold Bluff	Mrs. Irene Best, Downieville	23	20N	10E	MD	(Irelan 88:579-580; Crawford 94:266; Crawford 96:376; Mac Boyle 20:110; Logan 24:18; O'Brien 51:371; herein).
5	Gold Crown (Wonder)	Gold Crown Mining Corp.,	3	18N	10E	MD	(Logan 22:519; Ferguson and Gannett 32:102; herein).
		Alleghany	34	19N	10E	MD	
--	Hub						See Seven Aces
6	Irelan (Ireland)	Yuba-Irelan Mines, Ltd., 1921 Stockton Blvd., Sacramento, Calif.	11	18N	10E	MD	(Lindgren 00:8; Ferguson 15:179; Mac Boyle 20:92; Logan 22:506-507; Logan 24:17; Ferguson and Gannett 32:14, 127-128; herein).
7	Kate Hardy	H. E. Hawn, P.O. Box 748, Grass Valley, Calif.	29 32	19N	10E	MD	(Ferguson 15:181-182; Mac Boyle 20:95-97; Logan 21:475; Logan 22:507-508; Logan 24:17; Logan 29:166; Ferguson and Gannett 32: 89-91; O'Brien 51:372; herein).

LIST OF LODE GOLD MINES IN THE ALLEGHANY-DOWNIEVILLE AREA THAT HAVE BEEN ACTIVE SINCE 1942—Continued

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
--	Liberty (Macchaus)	Delbert R. Schiffer, et al., Nevada City	5	18N	10E	MD	Exploration work and some diamond drilling done between 1946 and 1951 by several lessors (Mac Boyle 20:29; O'Brien 51:372).
--	Macchaus						See Liberty
8	Morning Glory		34	19N	10E	MD	Leased by C. Hawkins who has done a minor amount of rehabilitation work. There has been no recent production. (Mac Boyle 20:105; Logan 22:509-510; Ferguson and Gannett 32:112).
9	Mugwump (Young America)	Mugwump Mining Co., The Vivians, Forest.	28	19N	10E	MD	(Preston 92:407; Crawford 94:275; Crawford 96:384; Mac Boyle 20:53; 133-134; Logan 22:143; Logan 29:194-195; Ferguson and Gannett 32:92-94; O'Brien 51:373; herein).
10	Oriental	Drescher Estate, Financial Bldg., 10th & J Sts., Sacramento and Mrs. W. E. Kliensorge, 2161 Hyde St., San Francisco	33 4	19N 18N	10E 10E	MD	(Lindgren 00:8; Ferguson 15:176-177; Mac Boyle 20:107-108; Logan 22:511; Logan 24:18; Logan 29:168; Ferguson and Gannett 32:26, 32, 98-101; Logan 35:3; Averill 42:33-35; O'Brien 51: 372; herein).
--	Oro	Dr. & Mrs. Phillip Newton, Oakland, Calif.	35 2	20 19	10 10	MD MD	Some work done in 1946 and 1947 by the Associated Metals Company of Seattle, Washington. (Mac Boyle 20:108; Logan 21:475; Logan 22:737; Averill 49: 122).
--	Osceola						See Red Star
11	Oxford	Oxford Quartz Mining Co., Downieville	26	20N	10E	MD	(Crawford 94:269; Crawford 96:381; Mac Boyle 20:109; Averill 42:35; O'Brien 51:371; herein).
12	Pilgrim (American Hill)		29	19	11	MD	American Hill Mines operated mine from Oct. 15 to Dec. 20, 1946; 600 tons ore yielded 145 oz. gold and 22 oz. silver. Six tons ore shipped to smelter. (Mac Boyle 20:112; Logan 29;168-169.)

LIST OF LODE GOLD MINES IN THE ALLEGHANY-DOWNIEVILLE AREA THAT HAVE BEEN ACTIVE SINCE 1942—Continued

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
13	Red Ledge		12	18N	9E	MD	Some recent surface exploration work done by several leasors. There is a 50-foot wide zone of mineralized quartz veinlets in serpentine. (Mac Boyle 20:114-115).
14	Red Star (Osceola, Yellow Jacket)	Tightner Mines Co., 58 Sutter St., San Francisco	34	19N	10E	MD	(Preston 92:407; Ferguson 15:173-174; Mac Boyle 20:108-109; Logan 22:511-512; Ferguson and Gannett 32:78, 79, 114-115, 119-120; O'Brien 51: 373; herein).
15	Roye-Sum	Not determined	4	18N	10E	MD	Old workings were cleaned out and sampled by several leasors; there was no production. (Ferguson and Gannett 32:98).
16	Ruby drift mine	Not determined	15	19N	10E	MD	Intermittant minor lode production from small veins which were encountered in bedrock below the channel. (Preston 93:406; Crawford 94:271-272; Crawford 96:382; Mac Boyle 20:56-57; Averill 42:38-42).
17	Seven Aces (Wyoming, Hub)	W. B. Brinker, et al., 140 Douglas St., San Francisco, Calif.	33	19N	10E	MD	Intermittent development work being done by the owner. (Ferguson and Gannett 32:102; O'Brien 51:372).
18	Seymour	Not determined	4	18N	10E	MD	A minor amount of development was done recently by several leasors.
19	Sixteen to One	Original Sixteen-to-One Mine, Inc., 235 Montgomery St., San Francisco	3, 4 34	18N 19N	10E 10E	MD MD	(Ferguson 15:175; Mac Boyle 20:122-124; Logan 21:475; Logan 22:143, 514-517; Logan 24:17, 18; Logan 29:171-172; Ferguson and Gannett 32:31, 33, 35, 38, 54, 106-110; Logan 35:3; Averill 42:44-47; Bowen and Crippen 48:78; Averill 49:122; O'Brien 51:373; herein).
20	Telegraph	Jack Sheedy, Downieville	4	20N	10E	MD	Small amounts of rehabilitation work done recently. (Preston 93:410-412; Mac Boyle 20:126; Logan 29: 187; Logan 34:3).

LIST OF LODE GOLD MINES IN THE ALLEGHANY-DOWNIEVILLE AREA THAT HAVE BEEN ACTIVE SINCE 1942—Continued

No.	Name of claim or mine	Owner (name and address)	Location				Remarks and references
			Sec.	T.	R.	B & M	
--	Tightner						Part of the Sixteen-To-One (Ferguson 15:171-173; Mac Boyle 20; 127-129; Logan 21; 475; Logan 22:143, 517-519; Logan 24:17, 83; Ferguson and Gannett 32:106-109; Bowen and Crippen 48:78; herein under 16-to-1 Mine).
--	Twenty-One						Part of the Sixteen-to-One Mine (Ferguson 15:174; Mac Boyle 20:130-131; Bowen and Crippen 48:78; herein under 16-to-1 Mine).
--	Wonder						See Gold Crown
--	Wyoming						See Seven Aces
21	Yellow Jacket (Colorado)	Yellow Jacket Cons. Gold Mines, Ltd., 120 Chester Ave., Bakersfield, Calif.	34	19N	10E	MD	Some development work done 1947. During 1952-1953, the Jolly Jack Company partially reopened the main adit. (Mac Boyle 20:81; Logan 22:511-512; Ferguson and Gannett 32:119-120).

HISTORY OF BORAX PRODUCTION IN THE UNITED STATES

By W. E. Ver Planck *

The American borax industry is very nearly synonymous with the California borax industry. In the latter part of the 19th century, however, borax production in Nevada equalled that of California and even exceeded it at times. Oregon also produced borax at about the same period.

Borax was one of the first of the nonmetallic mineral commodities to have been considered worthy of the attention of the prospector, the engineer, and the promoter. Like the precious metals, borax has held forth the enticing promise of fortunes to be made with little effort. To the popular mind, it is irrevocably associated with Death Valley and a host of semi-legendary episodes. While the borax industry can look back on a past that is not without its dramatic moments, today it is a mature industry in which profits are made only by hard work coupled with the best of engineering and business practices.

A century ago, borax was a high-priced commodity imported from England, mainly for pharmaceutical purposes. Consumption amounted to but a few hundred tons a year. The principal source of raw materials was the sassolite deposits of Italy, which were developed in the early 18th century. Prior to that time a very impure borax called tincal was obtained from the interior of Asia. Refineries were established first in Venice and later in other European cities and in England.

Lake County Period (1864-72). Borax was first detected in California in January, 1856, by Dr. J. A. Veatch while making an analysis of the water of Tuscan Springs in Tehama County. The search for a workable deposit culminated in September of the same year in the discovery of the small saline lake near Clear Lake in Lake County that has since been called Borax Lake. This lake, which occupies an isolated basin in an area of Quaternary volcanism, contains a strong brine, rich in sodium chloride, carbonate, and borate. In addition, the bottom mud was found to be crowded with borax crystals ranging up to several inches in length. Some time passed before the deposit could be studied and a company formed to work it, and it was not until 1864 that the California Borax Company with W. O. Ayers as Superintendent, actually produced borax.

The methods used by the California Borax Company were simple. Iron coffer dams, 4 feet square by 6 feet deep were floated out by means of a raft and dropped into the crystal-bearing mud. Then the mud within the coffer dam was shoveled out and the borax crystals were washed from it. In this way, and in spite of the loss of the small crystals, as much as 900 pounds of borax were obtained from the mud within a single coffer dam. The crystals recovered were refined by dissolving in hot water and recrystallization. From 1864 to 1868 an average of 300 tons a year of refined borax was produced, which sold for 28 to 35 cents per pound. This material according to an analysis made in 1865 was 99.95 percent pure.

Before long the company felt that the supply of crystals that could be recovered in this way was limited, and means of increasing the efficiency of the operation were considered. Plans were made to treat the lake brine itself, and bore holes were put down in order to search for an artesian source of borate brine. Work was begun on the recovery of borax from the mud, which was estimated to contain some 20 percent of borax. When leaching with hot water proved to be ineffective, a plant was made to "roast" the mud before leaching. Before the problem was solved, however, the lake was flooded, possibly from a flow of artesian water from a well the company sank, perhaps because the winters at that time were unusually rainy. In any case, no more borax was produced from Borax Lake. In 1934, M. Vonsen and G. D. Hanna visited the area, and found what was apparently one of the California Borax Company's cofferdams sunk in the mud near the center of the lake. Curiously enough they found that the mud contained several pounds per cubic foot of borax crystals, although reports contemporaneous with the mining activity agree that the supply of crystals had become seriously depleted by 1868.

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* Geologist, California State Division of Mines.

After the flooding of Borax Lake, the California Borax Company transferred its operations to a similar alkali lake called Little Borax Lake or Lake Hachinhama on the west side of Clear Lake near Mount Konocti. Some time in the 1930s the salines of Lake Hachinhama were flushed out with fresh water pumped from Clear Lake. Unlike Borax Lake, the mud of Lake Hachinhama contained no borax crystals, and it was necessary to devise a way of recovering borax from the mixed alkali brine. Fractional crystallization was tried, but while borax could be separated from sodium carbonate and salt in the laboratory by evaporation, the yield was disappointingly small when tried on a large scale. Finally the attempt to crystallize pure borax was given up, and it was found to be possible to crystallize a mixture of salts from which pure borax could be obtained by washing away the more soluble sodium carbonate and sodium chloride with cold water. The lake water was first partially concentrated by solar evaporation in shallow ponds floored with brick and asphalt and then concentrated to saturation by boiling. The hot concentrated liquor was then cooled in milk pans of 2 or 3 gallons capacity, because it had been found that the yield of borax was greater from a small volume of solution. At one time as many as 4,000 of these small crystallizing pans were in use. After the solution had cooled, the mixed crystals from the pans were washed with cold water, and the borax that remained was purified by recrystallization as had been practiced at Borax Lake. Borax was also recovered from the salt crust that formed when the lake dried up in summer. When the crust was removed it was renewed by efflorescence, and two or three crops could be gathered in one summer. This crust material was added to the evaporating ponds to increase the strength of the brine.

In 1872 ulexite, a sodium-calcium borate, was available in quantity in San Francisco; and the California Borax Company experimented with obtaining borax from it. Theoretically, if a calcium borate is treated with sodium carbonate, double decomposition takes place, producing insoluble calcium carbonate and borax that remains in solution. The Company planned to use the Hachinhama brine as a sodium carbonate solution, the comparatively small proportion of borax it contained being added to that obtained from the decomposition of ulexite. They found that this process was difficult to handle on a commercial scale. By prolonged boiling of a mixture of lake brine and ulexite and by using a substantial excess of ulexite, borax-rich liquor could be obtained, which, when cooled, yielded borax crystals. How successfully this was carried out is not clear. The California Borax Company remained active until 1874, and ulexite is reported to have been shipped to Lake County in bulk. Borax production from Lake Hachinhama, however, was reported only in 1872; but of course any borax produced by the treatment of ulexite should not properly be attributed to Lake Hachinhama.

Playa Period (1872-90). Small though the Lake County borax production was, it nearly eliminated imported borax from the American market. Moreover, borax was becoming a more familiar commodity, and the prospector was beginning to keep his eye open for it. Indeed, borax had been noted in the playas and saline lakes of California and Nevada before 1870, but this fact passed almost unnoticed. Columbus Marsh, Esmeralda County, in Nevada, later an important source of borax, was located in 1864 as a salt deposit. The salt was used in the Washoe process for treating gold and silver ore; and Dr. Partz, a metallurgist, identified borates in the Columbus Marsh salt. He obtained samples and sent them to the east as a matter of scientific interest.

About 1870, however, borax began to attract more attention. A ulexite cotton ball, said to have been picked up in Nevada by a teamster, reached the California Borax Company men who dispatched a prospecting party to search for the plane where it had been found. A San Francisco company attempted to obtain borax by evaporating the alkali water of Ragtown or Big Soda Lake in Churchill County, Nevada. In 1870 or 1871 William Troup found ulexite, first near Sand Springs in Churchill County, and later in Columbus Marsh. Apparently Troup had been looking for deposits of borates since 1860 when Dr. Veatch had told him that borates occurred in Mono Lake and probably were to be found in Nevada also. Troup prepared some borax by boiling a sample of the Sand Springs ulexite with sodium carbonate from Ragtown (Soda) Lake. Encouraged by this, he shipped 1700 pounds of ulexite from Columbus Marsh to San Francisco where it was converted to borax and sold.

By 1873, ulexite was being recovered on a small scale from a number of the Nevada borate playas, but this development attracted little attention outside the borax industry. Perhaps one reason that these early playa operations were unspectacular was the difficulty of obtaining borax from ulexite. A considerable quantity of ulexite was shipped to England for treatment as well as to San Francisco, and apparently to Lake County. In addition, refining on a small scale was carried out at the town of Columbus near Columbus Marsh, Nevada.

In October of 1872, F. M. Smith, later president of the Pacific Coast Borax Company, made a spectacular discovery that attracted wide attention. Smith was a prospector for gold and silver and at that time was operating a timber claim that overlooked Teels Marsh in Mineral County, Nevada. Out of curiosity, he took a sample of the powdery surface crust of the playa and left it to be assayed at Columbus, 16 miles away. So rich in borax was the sample that the news quickly spread and Smith only partially succeeded in locating the most favorable parts of the playa for himself. The task of location was made difficult and troublesome by a change in the regulations made just at this time. Previously, borax locations had been made under the saline laws of Nevada, which allowed a locator to take 160 acres. Now it was decided that borax land should be located as placer claims of 20 acres each. Smith had to relocate his property and temporarily lost control of some of it. Eventually, however, he and his brother obtained much of the best borax land and Smith Brothers became the largest of the borax producers in the 1870's and 1880's.

A close second among the early borax producers was the operations of John W. and Dennis Searles on what is now Searles Lake in San Bernardino County. About 1862 they were prospecting and mining in the Slate Range and may well have suspected the presence of borax in Searles Lake. Some ten years later, after the Teels Marsh discovery, Searles saw specimens of Nevada borax and realized that the same material occurred at Searles Lake. Accordingly, in April 1874, the Searles brothers, E. W. Shillings, and J. D. Creigh hurried to Searles Lake to locate borax land. As at Teels Marsh a host of other locators swarmed in, and here also the change from the 160-acre to the 20-acre law resulted in confusion. The Searles organization got into production in 1874, and on January 1, 1878 was incorporated as the San Bernardino Borax Mining Company with J. W. Searles as superintendent.

In the early 1870's borax producers sprang up like weeds on the playas of southeastern California and Nevada. Hanks (1883) lists 31 organizations that contributed all but between 2 and 3 percent of the total United States production of borates up to June 1, 1883. Because some of the organizations that Hanks lists produced as little as 1,000 pounds, is seems likely that the production of nearly a million pounds that he does not account for may have been contributed by literally hundreds of additional small, ephemeral enterprises. In California, the known activity was confined largely to Searles Lake, where, in addition to the Searles Brothers' San Bernardino Borax Mining Company, T. Dodge and Company reported production in 1876. Borax locations were made at Koehn Lake, Kern County in 1873, in Salt Wells Valley, Inyo County, in 1874, and in Death Valley at about the same time. The borax playas of Death Valley, however, were not to be productive until some 10 years later. With the exception of the San Bernardino Borax Mining Company, all the important early playa operations were in Nevada. At Hot Springs Marsh, Churchill County, borax was produced in 1871. At Sand Springs (Salt Wells) Marsh in the same county, the American Borax Company was active in 1870 and for a year or two after. Later the American Borax Company operated a short time 50 miles northwest at a playa close to the Central Pacific, now Southern Pacific, Railroad. In 1871 a second company also was active at Sand Springs Marsh. In Esmeralda County at least four borax companies were active at Columbus Marsh, including the Pacific Borax Company of F. M. Smith. In 1875 the Pacific Borax Company moved to Fish Lake Marsh, also in Esmeralda County, and was active there until at least 1884. At least one other company, Mott and Piper, was operating at Fish Lake Marsh in 1873. At Teels Marsh in Mineral County, was the large Smith Brothers operation, later called the Teels Marsh Borax Company, and probably others. At nearby Rhodes Marsh, Rhodes and Wasson were producing one ton a day of refined borax in 1874, and at a somewhat later date the Nevada Salt and Borax Company was producing both salt and borax.

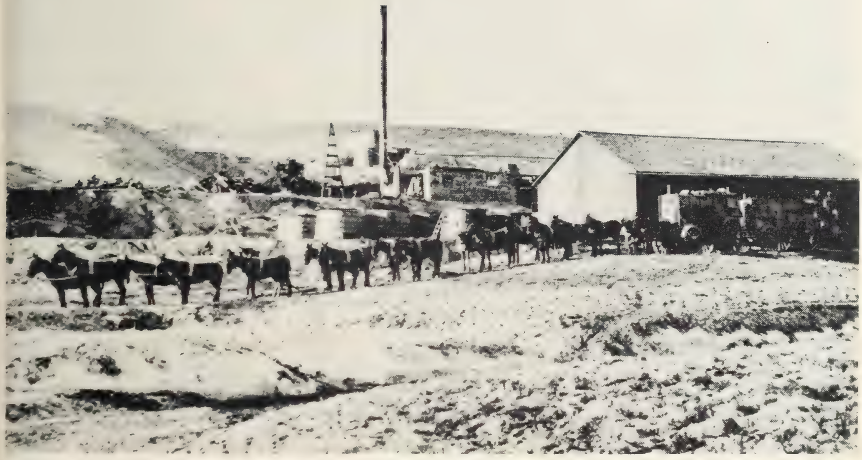

FIGURE 1. Harmony borax works, 1882-90. *Photo courtesy Pacific Coast Borax Company, reprinted from Division of Mines Bull. 170, Chapt. 8.*

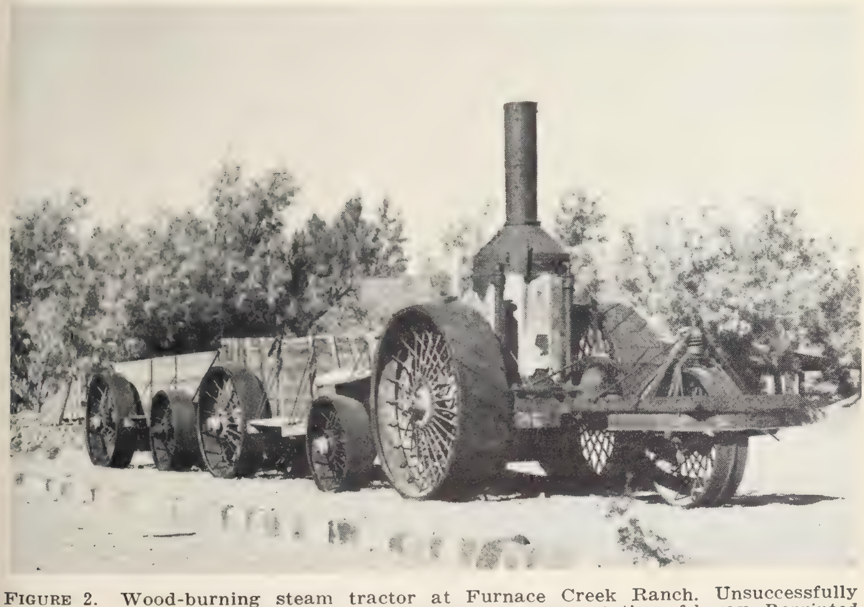

FIGURE 2. Wood-burning steam tractor at Furnace Creek Ranch. Unsuccessfully employed in an attempt to replace 20-mule team in transportation of borax. *Reprinted from Division of Mines Bulletin 170, Geologic Guide 1.*

Probably few of these ventures were financially successful. Their promoters were unbelieveably optimistic, for they overestimated the richness of the deposits and failed to realize that exacting specifications must be met in order to dispose of their products. Consumers, not failing to note the potential over-supply and anticipating a price fall, cut their orders to a minimum. Then some producers, frantic to dispose of their output under any conditions, began cutting prices; and the borax market collapsed. The price of refined borax at San Francisco dropped from an average of 25 cents per pound to as little as 6½ cents in 1874. Although the price later rose to between 11 and 13 cents and the demand for borax gradually expanded under the influence of the lower prices, all but a handful of the playa operations had been permanently closed by the late 1870's. When Hanks made his study of the borax industry in 1882, of a total United States production of nearly 42 million pounds of refined borax, nearly 24 million had come from Nevada, and five companies were productive. These were Smith Brothers at Teels Marsh, the Nevada Salt and Borax Company at Rhodes Marsh, the Pacific Borax Company and the Saline Valley Borax Company at Fish Lake Marsh, Nevada, and the San Bernardino Borax Mining Company, at Searles Lake, California. In Death Valley and the Amargosa Valley, several companies were active in 1882, but most of them had not started production.

Borates were noted in Death Valley at least as early as 1873, but not until 1880 was there any interest shown in them. In that year Aaron Winters, a resident of Ash Meadows, heard about the borax activities of Nevada from a traveler, and discovered the borate-bearing playas at the mouth of Furnace Creek. In 1882 he and several others discovered the Amargosa deposits. These claims he sold for a substantial sum to W. T. Coleman & Company, wholesale merchants. In 1883 the Greenland Salt and Borax Company and the Amargosa Mining Company were preparing to produce borax near the mouth of Furnace Creek. The Amargosa Mining Company also was developing deposits near Resting Springs in the Amargosa Valley. In 1884 Coleman organized two new companies, the Harmony Borax Mining Company to work the deposits near Furnace Creek, and the Meridian Borax Company with deposits in the Amargosa Valley.

Although Coleman began producing in 1883, the Eagle Borax Company produced some borax a little earlier. Isadore Daunet and several partners formed this company to work ulexite deposits near Bennett's Well in the southern part of Death Valley. They succeeded in producing some borax in 1882, but because of the difficulty in treating the ulexite ore, the physical discomforts of that area, and the long and difficult haul to the railroad, the enterprise failed.

Impure borax, not ulexite, was the rich ore of the playa borax operators. Calcium borates have never been found at Searles Lake; as for the Nevada playas, Le Conte's sketch map (Hanks, 1883, p. 52) of Rhodes Marsh shows areas of borax crust clearly differentiated from ulexite areas. To judge from the method of treatment, at Teels Marsh also borax must have been used. In the early 1880's ulexite was considered as the reserves of the future to be drawn upon after the borax was exhausted. At Rhodes Marsh samples, or more properly, specimens, of the crust contained as much as 50 percent borax. At Searles Lake the material treated averaged over a considerable period nearly 8 percent borax or a little less than three percent B_2O_3.

The recovery of borax from ulexite and other calcium borates is a comparatively difficult chemical operation that has perhaps been efficiently carried out only in the large refineries such as the one operated for many years at Bayonne, New Jersey. As the Lake County men discovered, the reaction with sodium carbonate is inefficient. That salt being abundant in Nevada, however, ulexite was nevertheless treated with sodium carbonate at the deposits, especially in the 1890s. An alternative procedure was the manufacture of boric acid, which could be converted to borax if desired. According to Hanks (1883), ulexite shipped to England was made into boric acid by treatment with hydrochloric acid. The refineries in San Francisco and at Columbus Marsh that operated during the 1870s used the Formhals process. Sulfur dioxide gas obtained by burning sulfur was injected into a mixture of ulexite and water. There resulted a boric acid solution that could be separated from an insoluble residue. Today boric acid is made with sulfuric acid, but this seems not to have been practiced in the 19th century.

Treatment of borax crusts, however, was relatively simple. Crude borax material was boiled in hot water until the borax dissolved, and then the hot solution was decanted from the insoluble residue into crystallizers for cooling. Borax crystals formed that were purified by recrystallization. Borax produced in 1883 by the San Bernardino Borax Mining Company, it is reported, contained 99.85 percent borax, while some from Esmeralda County, Nevada was 98.93 percent pure.

The Smith Brothers' plant at Teels Marsh used nine iron boiling tanks, 8 feet in diameter and 7 feet deep. They were heated by wet steam coils, that is, steam escaped from the submerged coils through small holes into the solution. The crystallizers were of galvanized iron. Two 24-inch boilers supplied steam to the boiling tanks. The Smith brothers' Pacific Borax works at Fish Lake Marsh contained six boiling tanks, 9 feet in diameter by 7 feet deep. Mud tanks were provided to receive the solids from the boiling tanks after the concentrated solution was drawn off. Here the mud was sampled. It could be sent back to the boiling tanks for retreatment or to a shallow tailings pond, where in time a borax-rich efflorescence would form similar to the natural borax crust of the playa. At the Searles Lake operation borax crust and borax crystals were dissolved in five boiling tanks, each of 7,000 gallons capacity. Thirty cylindrical galvanized iron crystallizing vats were used, while the recrystallizers were square and lined with galvanized iron. Fresh water came from fourteen 55-foot wells, and steam was generated by a boiler 42 inches in diameter. Fifty men and 35 animals were employed in 1882.

Fuel burned under the boilers of the borax plants was sagebrush, greasewood, and whatever other desert shrubs could be found. At Searles Lake, crude oil was substituted about 1887, but brush was still being burned by the Nevada plants in 1892.

The playa borax producers, being for the most part in isolated regions, had formidable transportation problems. Probably every user of borax is familiar with the 20-mule team borax wagons that the Pacific Coast Borax Company has adopted as its trademark and knows that they were used on the difficult run out of Death Valley. Used in pairs, these giant wagons could haul about 48,000 pounds of borax the 165 miles from Greenland to Mojave. It was John R. Spears, a New York journalist who visited the borax country in 1892, who did much to immortalize the Death Valley 20-mule teams. So completely did they capture his imagination, that he devoted an entire chapter of his book (Spears, 1892) to the borax wagons and the men who operated them. Actually, the Death Valley wagons were unusual mainly in their size. Freight wagons of less heroic proportions were widely used beyond the reach of the railroad. The San Bernardino Borax Mining Company, for example, also had its 20-mule teams, which operated from Searles Lake to Mojave, a trip that took 8 days.

The Nevada borax companies were more fortunate because the Carson and Colorado Railroad, which started building south from Mount House in 1881 and reached Keeler on Owens Lake in 1883, ran close to the borate playas of Esmeralda and Mineral Counties. The freight rate for borax from Columbus to San Francisco was reported to be $80 per ton in 1873, but only $12.50 in 1882, after the railroad was open.

Colemanite Period (1890-1907). Colemanite was discovered near Furnace Creek, Inyo County, late in 1882. The discovery was made by R. Neuschwander, and the new mineral was described by J. T. Evans of the California Academy of Sciences and by others. It was named for William T. Coleman, the Death Valley borax producer. In 1883, silver prospectors discovered colemanite and other borates in the Calico Mountains, 10 or 15 miles north of Daggett. Soon after the discovery the Coleman Company began buying up the more promising of the borate claims; but perhaps because colemanite was an unfamiliar borax ore that had to be mined by underground methods, development was slow. The principal colemanite operations were at Borate, about 3 miles east of the old silver mining town of Calico.

In 1888, while the deposits at Borate were being prepared for full production, W. T. Coleman and Company went into bankruptcy. The company was liquidated, and in March, 1890, F. M. Smith acquired Coleman's borax properties. Smith then consolidated all his holdings into one company, the Pacific Coast Borax Company, which was incorporated on September 5, 1890.

Properties included Smith's operations at Teels Marsh, Columbus Marsh, Rhodes Marsh, and Fish Lake Marsh in Nevada, and Coleman's properties in Death Valley, the Amargosa Valley, the new colemanite mines at Borate and a borax refinery at Alameda. The playa operations in Death Valley and the Amargosa Valley were closed, and between 1890 and 1907 the young Pacific Coast Borax Company obtained a large share of its borax ore from the mines at Borate. Few details of this operation have been published. The colemanite deposits occur in two zones separated by a stratigraphic thickness of about 50 feet. For a distance of about 1½ miles along the northeast slope of Red Mountain, the colemanite-bearing strata are honey-combed with numerous shafts, drifts, and cross cuts. When mining commenced the borate beds were thought to be comparatively uniform in width and grade, but development revealed that the borates occurred as disconnected pockets that were difficult to find. In the stopes hand-drilling was practiced, and the ore was sorted underground. In 1906 the ore was hoisted through two inclined shafts that were equipped with cages and 50-horsepower gasoline hoists. The deepest level was at about 600 feet.

At first, hand-sorting was the only beneficiation. The ore was hauled 12 miles to Daggett, the nearest railroad station, with two of the 20-mule team wagons that had been used in Death Valley. It was at this time that Spears saw the 20-mule teams and wrote the book that made them famous. The material shipped averaged about 35 percent B_2O_3.

The ore from Borate was treated in the refinery in Alameda, which, had originally been built by Coleman expressly for that purpose. There the lump ore was reduced by crushers, grinders of the coffee-grinder type, and buhr mills to a fine powder, and sized with silk screens. The ground ore was treated with a hot sodium carbonate solution in reaction tanks provided with mechanical agitators. The calcium carbonate precipitate, after several washings, was discarded and the borax-rich solution went to crystallizers where borax crystals formed on suspended wires. This borax was purified by recrystallization.

The first beneficiation plant was built in 1898 at Marion, 4 miles from Daggett. Rail connection with the mines at Borate was provided at the same time to replace the 20-mule teams. The plant as first designed was not satisfactory, and it was not put into regular operation until about 1900. This concentrator, as well as others built later, took advantage of the fact that colemanite decrepitates or flies to pieces when heated. By screening, the coarse material, mostly waste, can then be separated from the fines, mostly decrepitated colemanite. Borates other than colemanite do not decrepitate and cannot be recovered by the roasting process. The plant at Marion contained a Holthoff-Wethey roaster, a furnace of the reverberatory type with two hearths and mechanical rabble arms to move the ore forward. The temperature was 1200° F. The capacity was between 75 and 100 tons a day of crude ore.

The Pacific Coast Borax Company's holdings included the Chetco borate deposit on the Oregon coast a few miles from the California boundary. The chalk-like borate that occurs there in clay associated with serpentine was known at an early date and at one time was used locally as carpenter's chalk. A specimen reach San Francisco in 1871 and was identified as the calcium borate priceite. In 1872 some of the Oregon borate was used in San Francisco as a silver polishing compound. During 1891 and 1892 the deposit was worked under lease from the Pacific Coast Borax Company, and the output was sent by ship to the Alameda refinery.

In 1896 Smith went to England to explore the possibilities of developing an overseas market for borax. He decided to combine forces with a British chemical company; and the same year a new company, The Pacific Borax and Redwoods Chemical Works, Limited, was formed. Smith and other directors of this company organized Borax Consolidated, Limited, in January, 1899, with deposits and refineries in France, Chile, Peru, and Turkey as well as the United States and England.

It was decided to shift the refining operations in the United States to a more central location on the East coast; and a new plant was completed at Bayonne, New Jersey, late in 1898. Thereafter the Alameda refinery was operated on a reduced scale to supply the western market. These arrangements lasted until 1924 when the existing refinery at Wilmington was completed.

Although by 1890 colemanite was being mined at Borate, the playa operations continued for a number of years. In the year ending June 30, 1892, the production of refined borax was 6,690 tons. The Pacific Coast Borax Company produced 5,000 tons of this from the colemanite mines at Borate, the playa deposits at Teels Marsh and Columbus Marsh and the Chetco deposit. The San Bernardino Borax Company produced 540 tons at Searles Lake, Conn and Trudo, 360 tons at Saline Valley, Inyo County, in a playa operation that had begun in 1888, the Columbus Borax Company, 240 tons from Columbus Marsh, and the Nevada Salt and Borax Company, 550 tons from Rhodes Marsh. A company recovered borates from the playa in Salt Wells Valley, Inyo County, in 1894. In 1900, the Rose Valley Borax Company commenced playa operations south of Lake Alvord in southeastern Oregon, and in 1901 produced 400 tons of refined boric acid. The San Bernardino Borax Mining Company, however, last reported production in 1893. Plans were made to modernize the works in 1898, but the following year Borax Consolidated Ltd., parent company of the Pacific Coast Borax Company, obtained a controlling interest in the property and the project was abandoned. The last of the California playa operations appears to have been the one in Saline Valley which produced borax through 1907. In Nevada leasers operated on a very small scale until about 1908.

Several other interesting developments took place during this period when the older playa operations were gradually supplanted by colemanite mining. It was then that the low-grade borate-bearing shales of the Calico district, called borax muds at the time, were developed. Moderately to steeply dipping ore bodies containing as little as 10 percent B_2O_3 were mined by means of shafts and drifts. The low-grade ore was leached with sulfuric acid or, in a modification of the old Formhals process, with a sulfur dioxide solution; and a boric acid concentrate was obtained from the resulting weak solution by solar evaporation.

One of the pioneers of these ''mud'' operations was W. P. Bartlett, superintendent of the Western Minerals Company, whose mine and plant were near Calico. As early as 1897 Bartlett began the development of a sulfuric acid leaching process, and from 1901 to 1907, a 95 percent boric acid concentrate was produced experimentally. Despite an expenditure of about $140,000 the Western Minerals Company plant never got into full scale production.

Development of Judge A. J. Owens' Columbian mine, between Barstow and Yermo, was begun prior to 1894. In 1899 this property was sold to the Columbian Mining and Chemical Company and resold two years later to the Standard Sanitary Company of Philadelphia. A sulfur dioxide leaching plant was built, and the mine and plant were operated by the American Borax Company, an affiliate of the Standard Sanitary Company. Boric acid was produced from 1901 through 1907.

Judge Owens was also associated with the Columbus Borax Company, which had operated in Nevada. In 1897 or 1898 the Columbus Borax Company opened the Gem mine 4½ miles south of Daggett. Most of the output was obtained by W. P. Bartlett of the Western Minerals Company for the Stauffer Chemical Company under a working agreement with the Columbus Borax Company.

Still another enterprise was that of the Palm Borate Company, called the American Board of Promoters Boracic Acid Company before 1903.

A borate orebody of 5 to 8 percent B_2O_3 content was developed half to 1½ miles south of the main colemanite-bearing zone. Reorganized in 1907 as Borax Properties Incorporated, the company built a boric acid plant, which is said to have been operated for only 10 days.

At about this time also, the Frazier Mountain district in the northeast corner of Ventura County achieved its greatest prominence. Colemanite was discovered there in 1898 by McLaren, a prospector, who identified the white mineral that had previously been dismissed as "lime." The Frazier Borate Mining Company developed the Frazier mine close to the site of the original discovery. Production began in 1901, and in the same year the Stauffer Chemical Company bought the property. The nearby Columbus mine of the Columbus Borax Company was located in 1899 by B. F. Stevens. Production began in 1902, and the ore was sent for refining to M. Calm & Brothers in Jersey City, and Thomas Thorkildsen & Company bought the property. Both mines were handicapped by a difficult transportation problem. H. S. Gale (1914b) reports that from 1899 to 1907 inclusive, when the mines closed, the Frazier Mountain district produced 35,000 tons of crude ore, valued at $1,000,000. The value of the California production during those years ranged from over $2,000,000 in 1902 to a little more than $600,000 in 1903.

Death Valley Period (1907-1927). By 1900 it became apparent that the Pacific Coast Borax Company's mine at Borate would not last forever. By now the mine was 500 to 600 feet deep, and mining costs were rising. The Pacific Coast Borax Company began exploring Death Valley and the Amargosa Valley for a new orebody. Development of a new mine began in 1903. It was at the southeast end of the series of colemanite-bearing lake beds that angles across the Black Mountains of Inyo County, and it was called the Lila C. Three parallel colemanite beds 6 to 18 feet wide were traceable on the surface for 2500 feet, and the B_2O_3 content was reported to be 40 percent. This orebody was developed by inclined shafts and drifts.

Production could not begin, however, until transportation was provided. During the development stage access was by means of a special road that ran from the Lila C. southeastward close to the California-Nevada boundary through Mesquite Valley and State Line Pass to Manvel, a station on the now abandoned Ivanpah Branch of the Santa Fe Railway, 100 miles away. Over it wagons were drawn by steam traction engines. To the engineer of the mid-20th century it may be a surprise that mines and lumber companies quite commonly used steam traction engines at the turn of the century. The Frazier Borate Mining Company used them to haul borax ore from the Frazier Mountain district. Somewhat earlier they were used to haul salt on Danby Lake, San Bernardino County. Many of these machines were built by the Daniel Best Manufacturing Company of San Leandro, which constructed more than a hundred between 1889 and 1901. The 50-horsepower model of 1901 weighed 15½ tons and could run at 3 or 4 miles per hour. A vertical boiler 4 feet in diameter and 5 feet 10 inches high provided steam for two 9-by 9-inch cylinders geared to the inner periphery of the driving wheels. The two rear wheels were 8 feet in diameter with tires ¾-inches thick and from 24 to 60 inches wide. The single front wheel was 5 feet in diameter. The Best Company also made

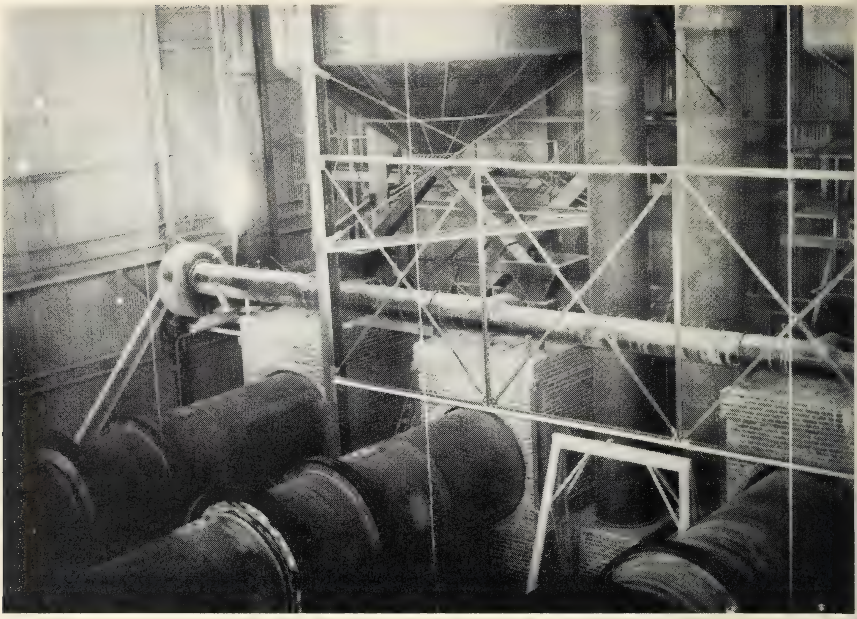

FIGURE 3. Rotary roasters at mill of Pacific Coast Borax Company.
Photo by E. Huguenin, 1916.

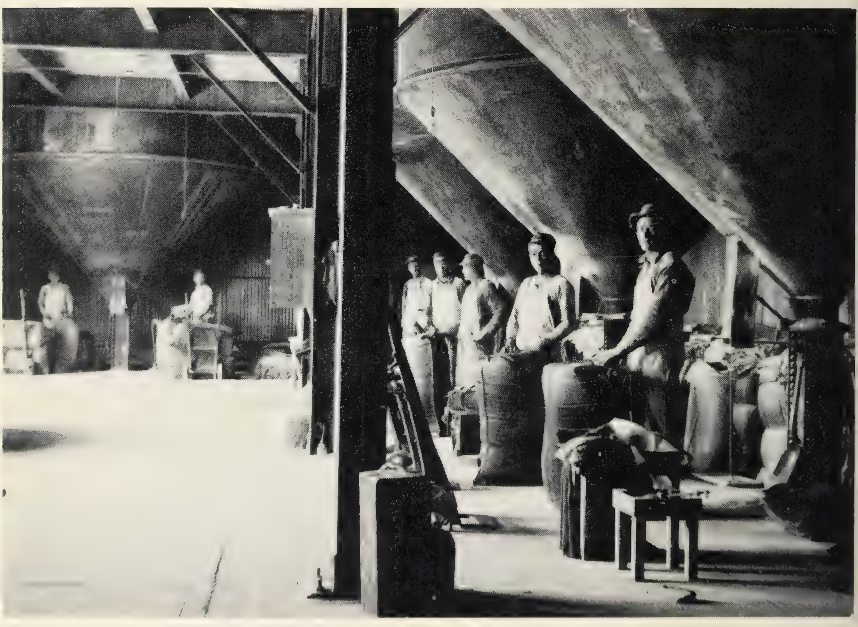

FIGURE 4. Sacking concentrates at Death Valley Junction.
Photo by E. Huguenin, 1916.

n ore wagon of 16 tons capacity, two of which were commonly pulled y one engine.

Traction engines, however, proved inadequate; and in 1905 the Pa- ific Coast Borax Company commenced building the Tonopah and Tide- ater Railroad northward from Ludlow on the Santa Fe. The route as east of Death Valley through the Amargosa Valley not far from the ila C. Mine, and the destination was the new mining camp of Bull- rog over the state boundary in Nevada. Early in 1907 construction eached the borax area. The Lila C. was connected to the railroad by a pur, and that summer the first shipment of colemanite went out over he T. and T. Immediately the mines at Borate and the mill, shops, and ther facilities at Marion were abandoned; and all activities were trans- erred to the new mine. For a time the Lila C. ore was shipped without eneficiation, but in 1912 a calcining plant was in operation. This one ontained rotary calciners constructed in such a way that the colemanite id not come in direct contact with the flame.

It was more than coincidence that the year the Lila C. mine opened, he price of borax dropped from 6½ to 7 cents a pound to 4½ to 5½ cents. o doubt it was hoped that the lower price made possible by cheaper ining would expand the borax market; the drop in price also caused he near-permanent shutdown of all the older borax operations, includ- ng the Saline Valley playa operation, the low-grade ''mud'' deposits f Daggett, and the colemanite mines at Frazier Mountain.

The Pacific Coast Borax Company was not to be alone in the field for ong, however, for in November 1907 colemanite was discovered in ick Canyon, Los Angeles County, 5 miles north of Lang on the South- rn Pacific Railroad and only about 30 miles from Los Angeles. The eposit was acquired by the Sterling Borax Company, a consolidation f borax interests formed late in 1907. These included the Stauffer hemical Company's Frazier Borate Mining Company with holdings n the Frazier Mountain district, the American Borax Company, which wned a deposit in Inyo County in addition to the boric acid works at aggett, the Brighton Chemical Company which operated a refinery in ennsylvania, and Thomas Thorkildsen and Company with a refinery n Chicago. The steeply dipping Tick Canyon orebody was traceable for ,000 feet on the surface and averaged 16 feet wide. Because it was nuch richer than the Daggett ores and far more accessible than the nine at Frazier Mountain, development was pushed, and production egan in 1908. Ore obtained by underground mining was calcined at he mine and shipped to Lang over a railroad built in Tick Canyon. From Lang the ore went to the Company's numerous refineries. The Sterling Borax Company produced a substantial share of the colemanite mined from 1908 to 1920. Faced with an ever-declining price for borax and, as the mine grew deeper, with rising mining costs, the company finally sold the property to the Pacific Coast Borax Company in 1921, which operated it through 1923. The plant was dismantled in 1926.

Meanwhile there was renewed activity in the Frazier Mountain district. The Russell Borate Company was formed in 1907, and during 1909, 1910, and 1911, developed the Russell mine between the Frazier mine and the Columbus mine. Production began in November 1911 and continued until 1913. The property was sold to the Stauffer Chemical Company. Some prospecting was done north of Frazier Mountain in 1917, but no ore was produced. The Columbus mine was reopened in

1912 by the National Borax Company, and production was reported in 1912 and 1913. Afterwards the property came into the control of Pacific Coast Borax Company interests and was not operated again.

In the Calico Mountains development of the Neel Borate mine, on Pacific Coast Borax Company property, began in 1915, and a modest tonnage of colemanite was produced from 1920 to 1924 inclusive. This work was done by D. D. Connell under contract. Others also conducted small scale scavenging operations among the old workings at Borate until the mid-1920s. Other work was done by the Union Borax Company, which was a subsidiary of the Standard Sanitary Company and affiliated with the American Borax Company. From 1919 to about 1924 claims adjoining the old mines at Borate were explored in the hope of finding rich pockets of colemanite. Workings include a shaft 640 or more feet deep and a long cross cut. There is no record of production.

Back in Death Valley the Lila C. mine began to show signs of exhaustion, and in 1914 the Pacific Coast Borax Company prepared to mine a new group of orebodies to the northwest in the Furnace Creek area. A new beneficiation plant was constructed at Death Valley Junction, and the narrow gage Death Valley Railroad was built approximately parallel to the route of the present State Highway 190. The camp at the western terminal of the Death Valley Railroad was called Ryan, the same name that had been used for the camp at the Lila C. mine. The Lila C. was closed and operations transferred to the new mines in January 1915. At the new Ryan was the Biddy McCarty mine. Others in the vicinity were the Lower Biddy, the Grand View, the Oakley, the Played Out, and the Widow. Mining was carried out largely by means of glory holes. Ore from the various workings was taken by 24-inch gage cars pulled by gasoline locomotives to the main ore bins at Ryan.

The beneficiation plant at Death Valley Junction contained four rotary calciners which, like those at the Lila C. mine, contained an inner chamber to keep the colemanite from direct contact with the flame. The kiln temperature was 1300° F, and the minus 24-mesh concentrate, which amounted to 44 percent of the plant feed, contained 42 percent B_2O_3. The tailings contained 4 percent B_2O_3.

About 1917 two more rotary calciners were installed, and gravity concentrating equipment was added to supplement the calciners, which were ineffective in recovering borates other than colemanite. The plus 24 mesh material that had not decrepitated was recrushed to minus $\frac{1}{4}$-inch and sized with 24 mesh screens. Oversize was treated in Hartz jigs and minus 24 mesh by Wilfley tables. Capacity of the plant was 300 tons per day.

In 1914 F. M. Smith was forced to sell his interest in Borax Consolidated, Ltd., because of a series of unfortunate private investments. He seems, however, to have been determined to get back into the borax business; but an opportunity did not immediately occur. In 1919 or 1920 he organized the West End Chemical Company for the purpose of recovering borax and potash from Searles Lake, but this enterprise did not immediately bear fruit. Late in 1920 John Perkins, a prospector, discovered colemanite in White Basin in the Muddy Mountains, Clark County, Nevada. F. M. Lovell and George Hartmen then began a systematic search for an extension of the White Basin deposits and the following January discovered the much larger deposits in nearby Callville, Wash. F. M. Smith purchased the Callville, Wash. property for

$250,000, and the West End Chemical Company's Anniversary mine made its first shipment in July 1922. The mine closed in 1927 after producing an estimated 100,000 tons of ore with a B_2O_3 content of 25,000 tons.

In White Basin a lively controversy arose over the ownership of the colemanite deposits. The United States Borax Company, an affiliate of the Pacific Coast Borax Company, purchased the deposits from the discoverer and covered them with lode claims. About 1924 the American Borax Company, having abandoned its efforts to develop a deposit in the Calico district, blanketed these lode claims with placer claims and commenced mining operations. At length the United States District Court at Carson City, Nevada, decided in favor of the United States Borax Company, leaving that company free to sue the American Borax Company for trespassing.

One of the last discoveries of colemanite was the deposit now known as the Gerstley mine near Shoshone, Inyo County. It was found by a prospector some time after 1920. The deposit is on State land and since its discovery has been leased to Pacific Coast Borax Company interests. Until May 7, 1936, it was held in the name of C. M. Rasor and since that date by the United States Borax Company. Production began late in 1924. One cannot but wonder if the Pacific Coast Borax Company, which had replaced the mine at Borate with the Lila C., and the Lila C., with the Ryan group was about to transfer its operations once more. The question is academic, however, for in 1925 came the discovery of the rich sodium borate orebodies of the Kramer district that rendered all the colemanite mines submarginal.

Kramer Period (1927-Present). Borates were first noted in the Kramer district more than 10 years before the important discoveries. Dr. J. K. Suckow found colemanite quite by accident in a well being drilled for water. The announcement was made in the fall of 1913. Most of the agricultural entries in the vicinity were released and mining claims, mostly placer claims, located. The Pacific Coast Borax Company and affiliated organizations acquired as many as possible of these privately held claims, including Suckow's discovery claim.

The early exploratory work was dilatory and discouraging. Most of it was done near Suckow's discovery well, from a mile to 3 miles west of the sodium borate orebody. Much of it was done by the Pacific Coast Borax Company. Ulexite and colemanite that occurred as nodules in lake beds were encountered in prospect shafts and drill holes, and the limits of the western part of calcium borate body were defined.

An interesting phase of the early exploratory work was the production of a modest tonnage of calcium borate ore in 1925. The Suckow Chemical Company, J. K. Suckow, President, continued work somewhat east of the discovery well and after several failures, including the Suckow Number One shaft, located a promising body of calcium borates. The mining shaft sunk to reach it, known as the Suckow Number Two shaft or the Suckow Colemanite mine, encountered the borates at a depth of 210 to 280 feet. They were in the form of nodules of colemanite with ulexite up to a maximum of one foot in diameter that ranged from masses of compact colemanite to borate and clay mixtures. Contemporary reports describe the deposit as being of rather lower grade than the colemanite deposits being worked at the time. This mine was not operated in 1926.

Meanwhile, William M. Dowsing and J. L. Hannam discovered the more important sodium borate body in the spring of 1925, but their discovery was kept as a closely guarded secret. After proving the deposit with a series of holes in the central part of the orebody, they sold their claims to the Pacific Coast Borax Company early in 1926. That August a shaft reached the ore, and production from the Baker mine, as the new mine was called, began in 1927. The colemanite mines of the Pacific Coast Borax Company, except for the Gerstley mine, were closed in June, 1927.

Soon after the Pacific Coast Borax Company began developing the new property a new sodium borate was recognized; and its analysis was reported by the Company laboratory at Wilmington, California, on August 18, 1926. The new mineral was named rasorite after Clarence R. Rasor, field engineer of the United States Borax Company. In the meantime, W. T. Schaller obtained some samples of the Kramer ore and determined the properties of the new mineral. Not knowing that the Pacific Coast Borax Company was already using the name rasorite, Dr. Schaller called the new mineral kernite. Largely because Dr. Schaller had followed the unwritten rules that govern the naming of new minerals, the name kernite has gradually supplanted the earlier name.

One reason that the Pacific Coast Borax Company pushed the development of the new orebody at Kramer was the rising output of borax from Searles Lake. After the San Bernardino Borax Mining Company ceased its crustal operations in 1893, Searles Lake became dormant. About 1908 the California Trona Company was incorporated for the purpose of producing soda ash both from the brine and from reefs of trona on the east side of the lake. This operation failed in 1909 but was reorganized as the American Trona Corporation. Meanwhile the shortage of potash that became acute during World War I began to develop, and Searles Lake was realized to be an important potential source of that commodity. Development work on the treatment of the complex lake brine was carried out by at least three organizations; the American Trona Corporation, Borosolvay, and the West End Chemical Company. Soon it became apparent that borax would be an unavoidable byproduct.

In 1913 the American Trona Corporation began work on a plant to produce potassium chloride, borax, and other salts by treating 2 million gallons of lake brine a day. The Mining and Scientific Press (1914) speculated that the sale of potash would support the entire operation and that the byproduct borax, the estimated production of which approximated the entire world's consumption, could be sold for whatever the market would bring.

As it turned out, the treatment of the brine was far more difficult than had been supposed. The American Trona Corporation's first plant was a failure and had to be redesigned. Finally in 1916, both the American Trona Corporation and the Borosolvay plant, which was owned by the Pacific Coast Borax Company and operated by the Solvay Process Company, succeeded in producing comparatively impure potash in highly inefficient plants that were profitably operated only during the war-stimulated shortage of potash. The Borosolvay plant was closed in 1920, and there is no record of borax production. The American Trona Corporation first produced borax in 1919. Following the war the American Trona Corporation initiated an intensive research program that enabled it to reduce costs and improve the quality of its products. Reorganized as the American Potash & Chemical Corporation, the company is now an important manufacturer of chemicals and produces a significant share of the world's supply of borax.

It has already been mentioned that F. M. Smith's West End Chemical Company built an experimental plant on Searles Lake about 1920 and attempted to produce borax and potash. The process was not a success, and the plant was redesigned to recover soda ash and borax. Production of soda ash began in 1927 and of borax in 1930. A comparatively small production of borax from Owens Lake began in 1929. It is recovered by the Pittsburgh Plate Glass Company's soda ash plant at Bartlett.

In the Kramer district, the Suckow Chemical Company and the Western Borax Company, in addition to the Pacific Coast Borax Company, have mined borax and kernite. The Suckow mine was 1½ miles west of the Pacific Coast Borax Company's Baker mine. Development began in the latter part of 1926, and production started in December, 1929. A comparatively small tonnage of borax had been mined when the Suckow Chemical Company became involved in litigation with the Pacific Coast Borax Company, and the mine was closed in April, 1932. The larger company obtained control of the Suckow mine; and since 1935, as the West Baker mine, it has been an important unit of the Pacific Coast Borax Company's operations.

The Western mine lies west and south of the Pacific Coast Borax Company's Baker mine. This property was developed by W. M. Balling and associates, who previously had explored some miles to the west and beyond the limits of the calcium borates. Kernite was discovered on what was to be the Western Borax mine in July, 1927. Balling transferred his interests to the Western Borax Company and remained as Superintendent of the Western Borax mine. Production began in November, 1928, and continued until mid-1933, when the property was sold to Borax Consolidated Ltd., parent company of the Pacific Coast Borax Company. The total production of the mine is estimated to have been 160,000 tons of crude ore at the time of its closing. As the result of action by the Federal Government, however, the Pacific Coast Borax Company was not permitted to acquire title to a 10-acre portion of the Western Borax Company property known as the Little Placer. Late in 1954 a group including Harvey S., Henry T., and Seeley G. Mudd obtained a Federal lease on the Little Placer and are preparing to produce borax.

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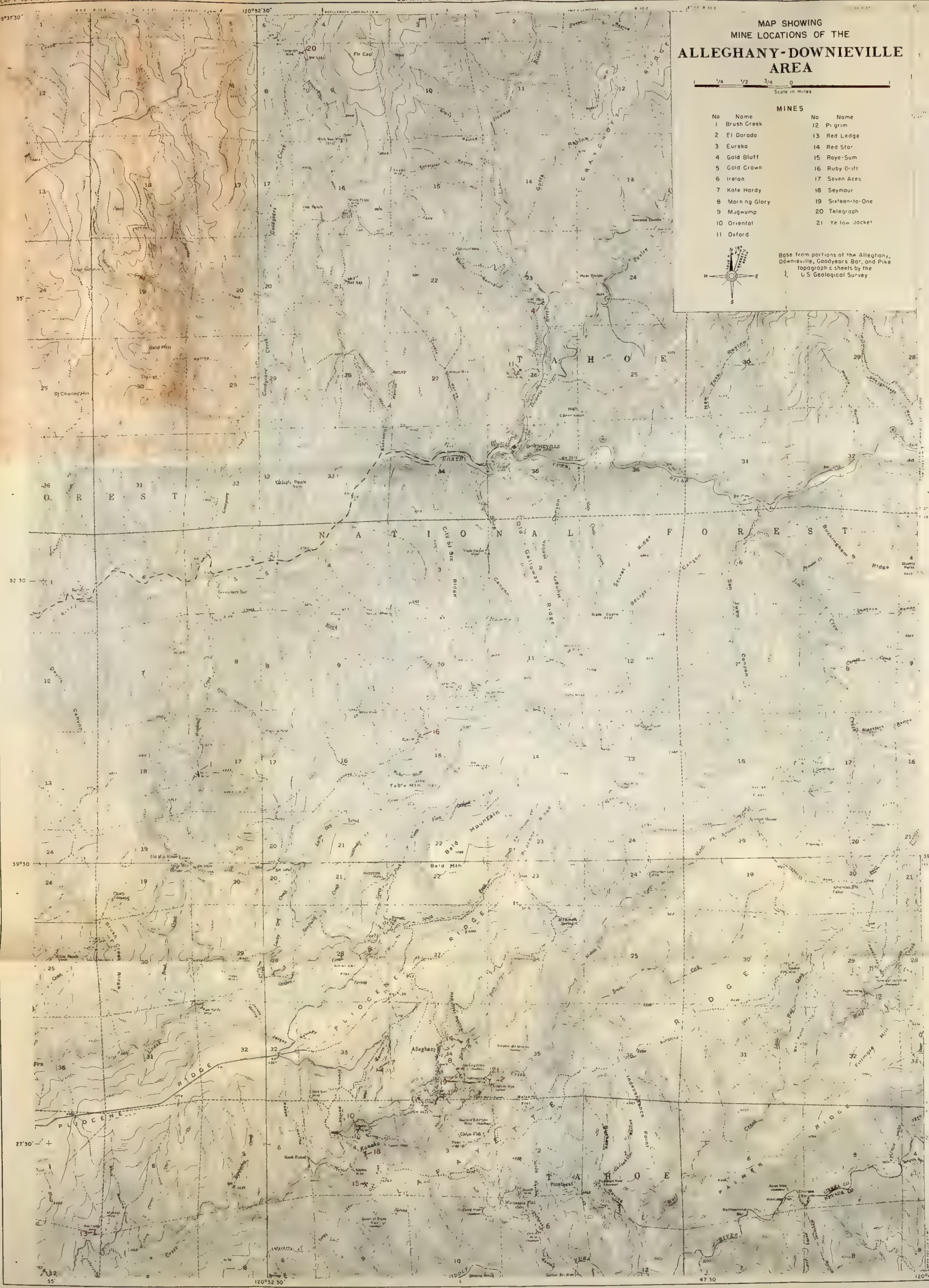

MAP SHOWING
MINE LOCATIONS OF THE

ALLEGHANY-DOWNIEVILLE AREA

Scale in miles

MINES

No	Name	No	Name
1	Brush Creek	12	Pilgrim
2	El Dorado	13	Red Ledge
3	Eureka	14	Red Star
4	Gold Bluff	15	Roye-Sum
5	Gold Crown	16	Ruby Drift
6	Irelan	17	Seven Aces
7	Kate Hardy	18	Seymour
8	Morning Glory	19	Sixteen-to-One
9	Mugwump	20	Telegraph
10	Oriental	21	Yellow Jacket
11	Oxford		

Base from portions of the Alleghany, Downieville, Goodyears Bar, and Pike topographic sheets by the U S Geological Survey

1/4
1/2
3/4
0
1
N
W
E
S
39°37'30"
120°52'30"
35'
32 30
39°30
27'30"
120°45'
47 30
TAHOE
NATIONAL
FOREST
DOWNIEVILLE
Alleghany
Fir Cap
Bald Mtn
St Charles Hill
Grizzly Peak
Table Mtn
Bald Mountain
City of Six Ridge
Goodyears Creek
Goodyears Bar
North Yuba River
PLIOCENE RIDGE
RIDGE
LAFAYETTE
PALMER RIDGE
CRAYCROFT RIDGE
Second Divide
Kentucky Ridge
Buckingham Ridge
Secret Canyon
San Juan Canyon
Brush Creek Ridge
Independence Point
Forest
Chips Flat
Minnesota Flat
Wash Road
American Flat
Middle Yuba
SIERRA CO
NEVADA CO

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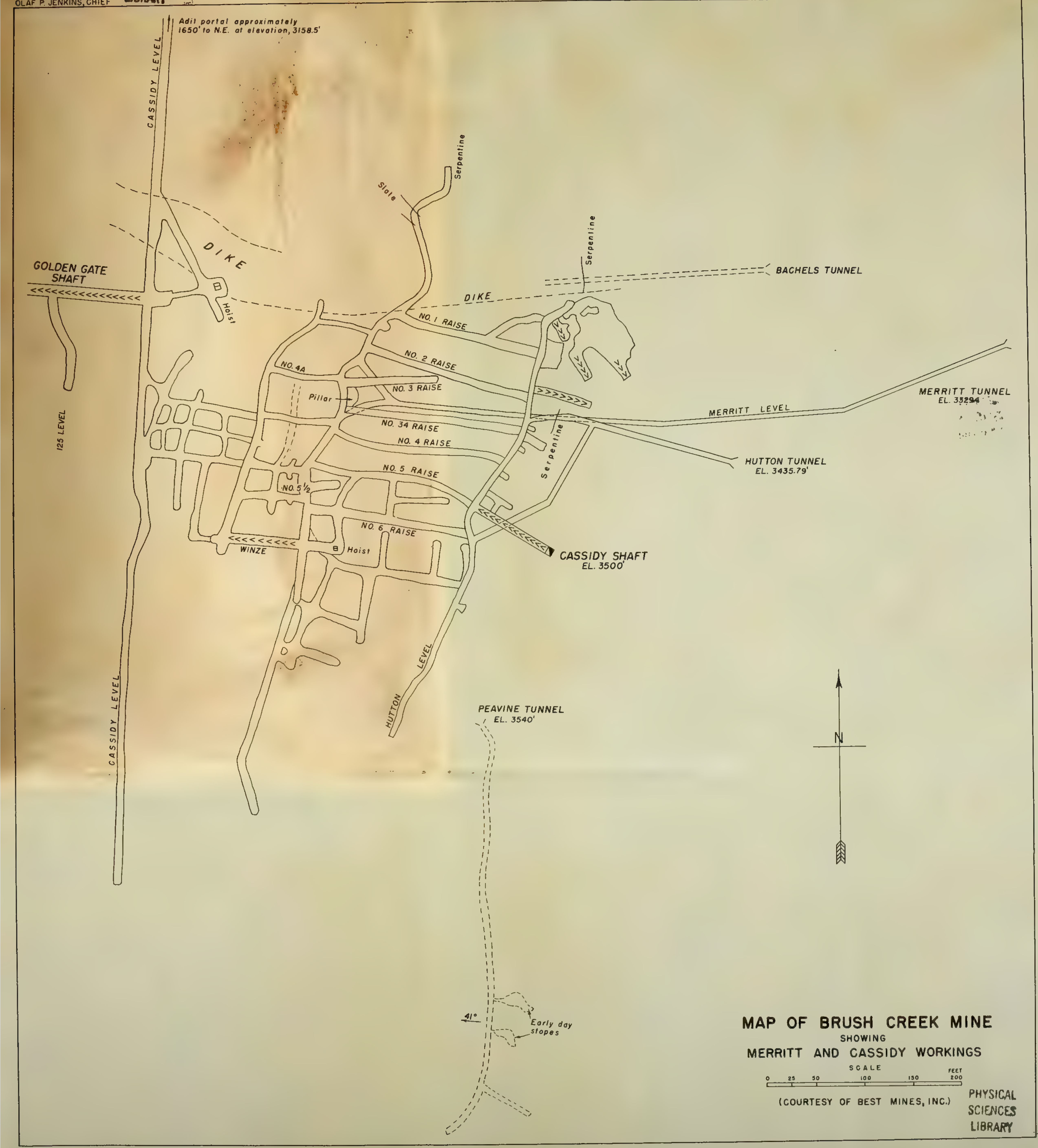
Adit portal approximately 1650' to N.E. at elevation, 3158.5'
CASSIDY LEVEL
Serpentine
Slate
DIKE
Serpentine
BACHELS TUNNEL
GOLDEN GATE SHAFT
Hoist
DIKE
NO. 1 RAISE
NO. 2 RAISE
NO. 4A
NO. 3 RAISE
Pillar
MERRITT TUNNEL
EL. 3529.4
MERRITT LEVEL
125 LEVEL
NO. 34 RAISE
NO. 4 RAISE
Serpentine
HUTTON TUNNEL
EL. 3435.79'
NO. 5 RAISE
NO. 5 1/2
NO. 6 RAISE
WINZE
Hoist
CASSIDY SHAFT
EL. 3500'
HUTTON LEVEL
PEAVINE TUNNEL
EL. 3540'
CASSIDY LEVEL
N
41°
Early day stopes
SCALE
0
25
50
100
150
200
FEET

MAP OF BRUSH CREEK MINE
SHOWING
MERRITT AND CASSIDY WORKINGS

(COURTESY OF BEST MINES, INC.)

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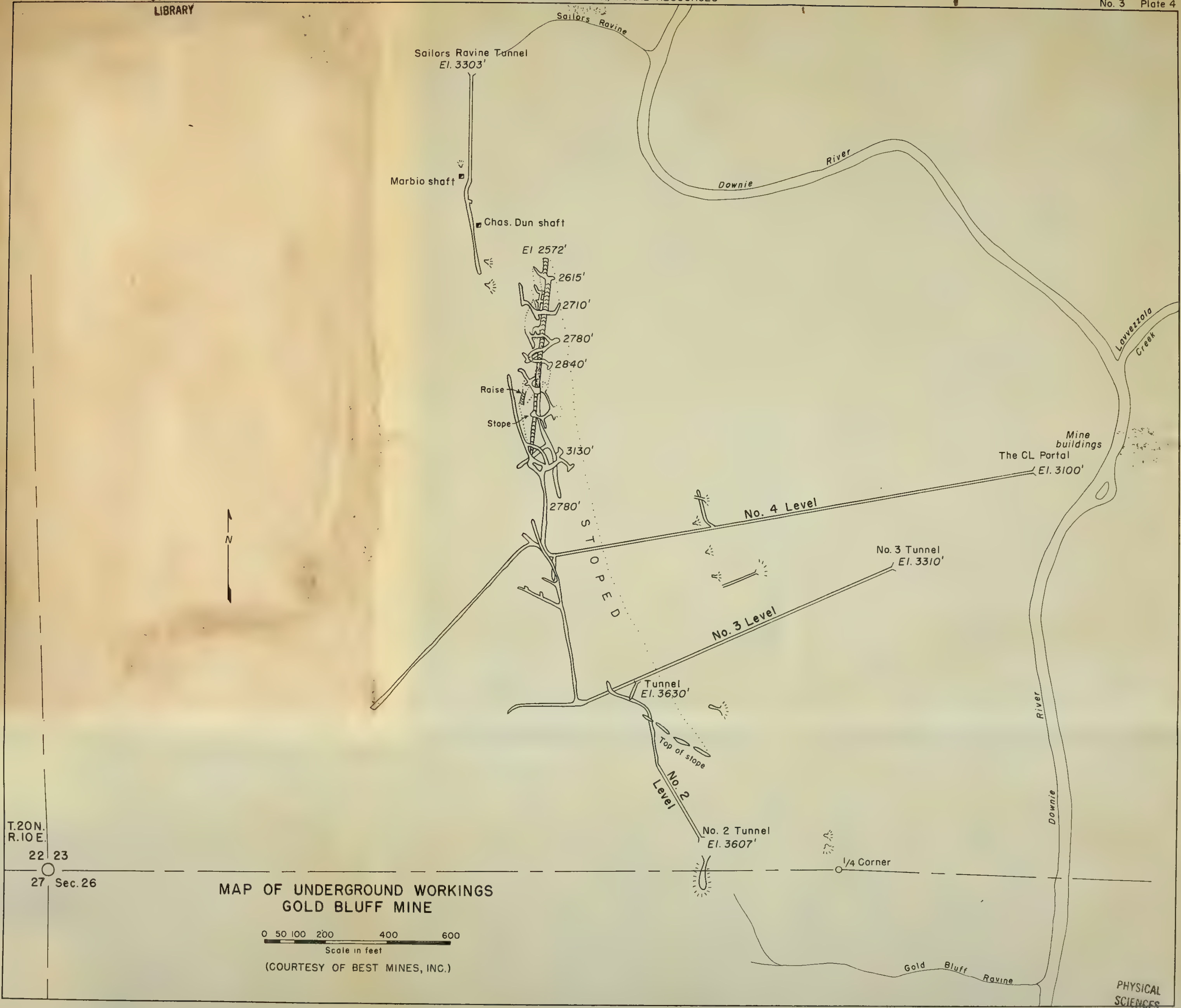
Sailors Ravine
Sailors Ravine Tunnel
El. 3303'
Marbio shaft
Chas. Dun shaft
El 2572'
2615'
2710'
2780'
2840'
Raise
Stope
3130'
2780'
STOPED
Downie River
Lavezzola Creek
Mine buildings
The CL Portal
El. 3100'
No. 4 Level
No. 3 Tunnel
El. 3310'
No. 3 Level
Tunnel
El. 3630'
Top of stope
No. 2 Level
No. 2 Tunnel
El. 3607'
River
Downie
N
T.20 N.
R.10 E.
22
23
27
Sec. 26
1/4 Corner
Gold Bluff Ravine
0 50 100 200 400 600
Scale in feet

MAP OF UNDERGROUND WORKINGS
GOLD BLUFF MINE

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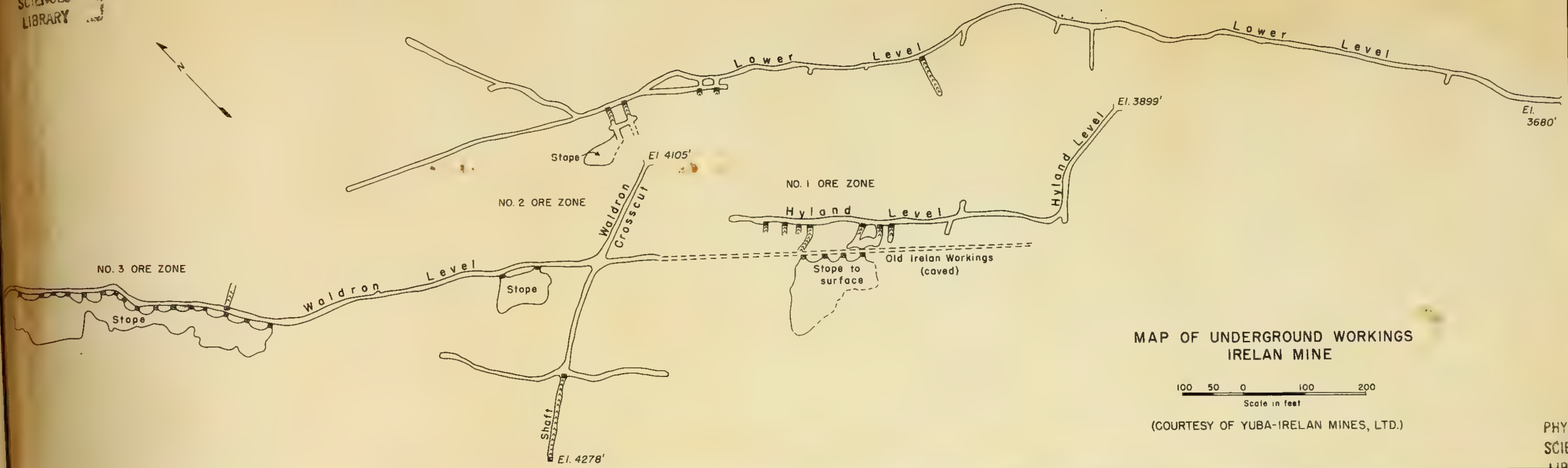
N
Lower Level
Lower Level
El. 3680'
El. 3899'
Hyland Level
Stope
El 4105'
NO. 1 ORE ZONE
NO. 2 ORE ZONE
Waldron Crosscut
Hyland Level
NO. 3 ORE ZONE
Waldron Level
Stope
Stope to surface
Old Irelan Workings (caved)
Stope
Shaft
El. 4278'
100 50 0 100 200
Scale in feet

MAP OF UNDERGROUND WORKINGS
IRELAN MINE

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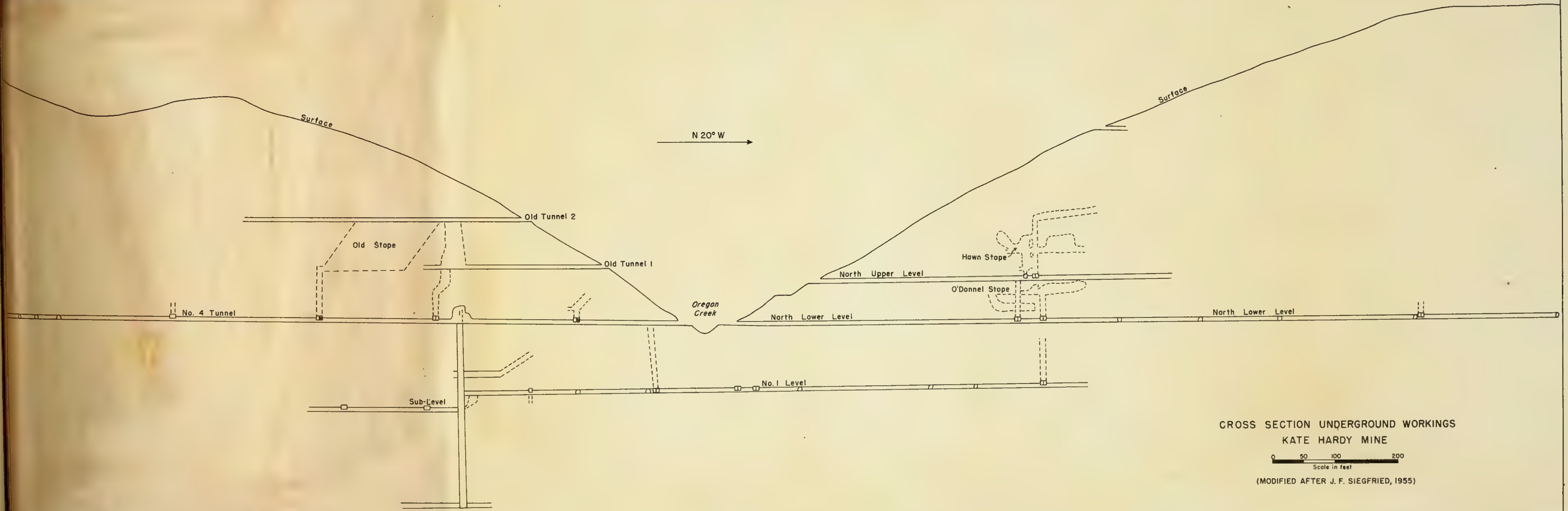
Surface
Old Tunnel 2
Old Stope
Old Tunnel 1
N 20° W
Surface
Hawn Stope
North Upper Level
O'Donnel Stope
No. 4 Tunnel
Oregon Creek
North Lower Level
North Lower Level
No. 1 Level
Sub-Level
0 50 100 200
Scale in feet

CROSS SECTION UNDERGROUND WORKINGS
KATE HARDY MINE

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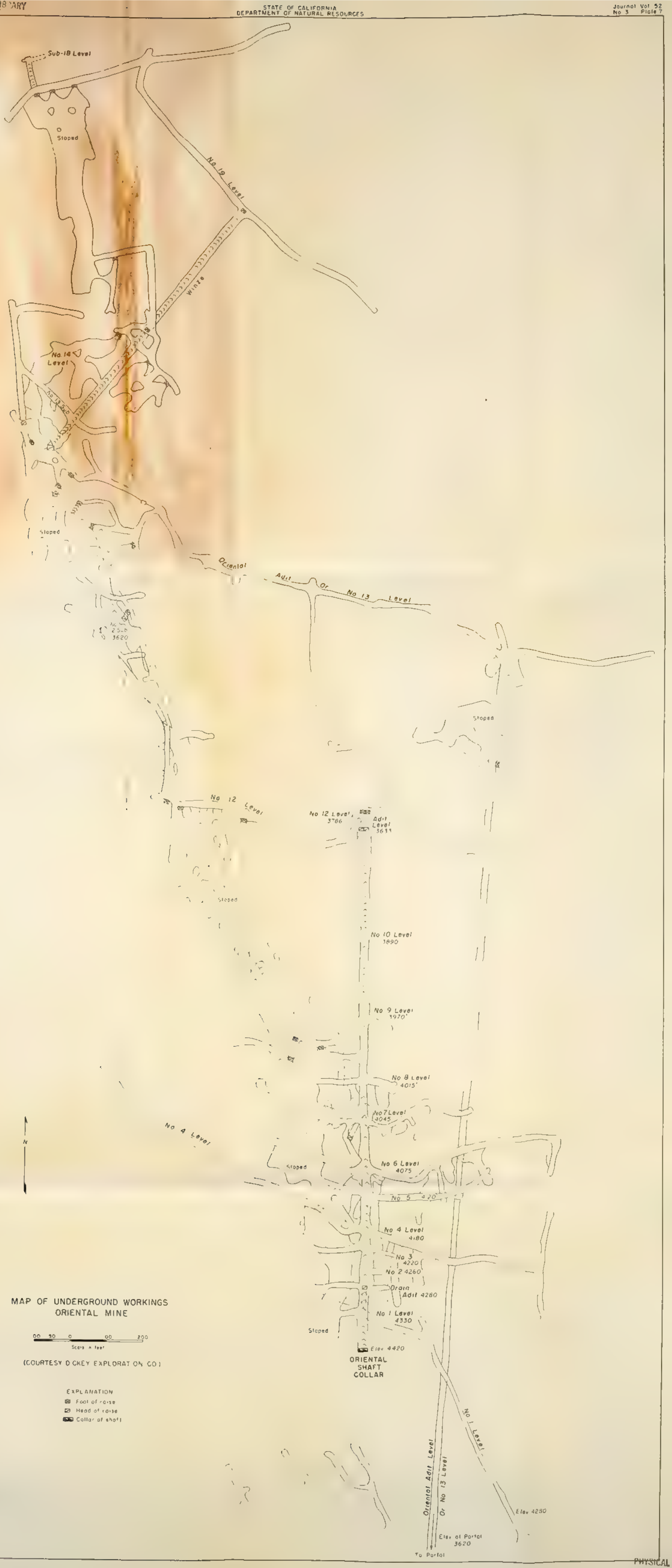
Sub-18 Level
Stoped
No 19 Level
Winze
No 14 Level
No 13 Sub
Stoped
Oriental Adit or No 13 Level
No 2 Sub 3620
Stoped
No 12 Level
No 12 Level, 3786
Adit Level 3611
Stoped
No 10 Level 3890
No 9 Level 3970'
No 8 Level 4015'
No 7 Level 4045
No 4 Level
Stoped
No 6 Level 4075
No 5 4120
No 4 Level 4180
No 3 4220
No 2 4260
Drain Adit 4280
No 1 Level 4330
Stoped
Elev 4420
ORIENTAL SHAFT COLLAR
No 1 Level
Oriental Adit Level Or No 13 Level
Elev 4280
Elev of Portal 3620
To Portal
N
100 50 0 100 200
Scale in feet
EXPLANATION
Foot of raise
Head of raise
Collar of shaft

MAP OF UNDERGROUND WORKINGS
ORIENTAL MINE

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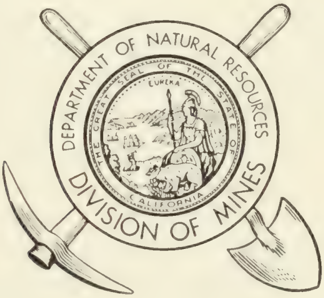
Vol. 52 OCTOBER 1956 No. 4

CALIFORNIA JOURNAL
OF
MINES AND GEOLOGY



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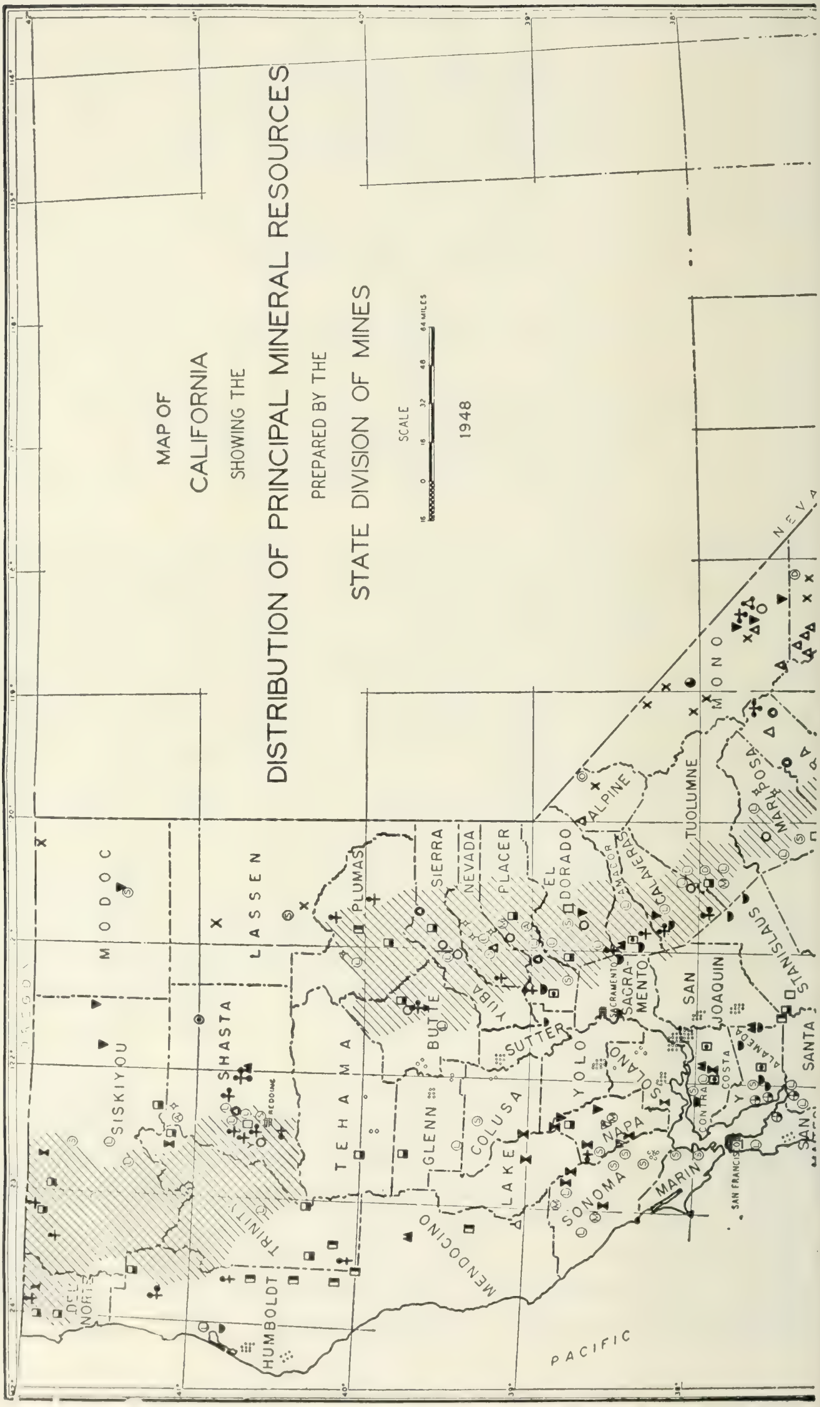
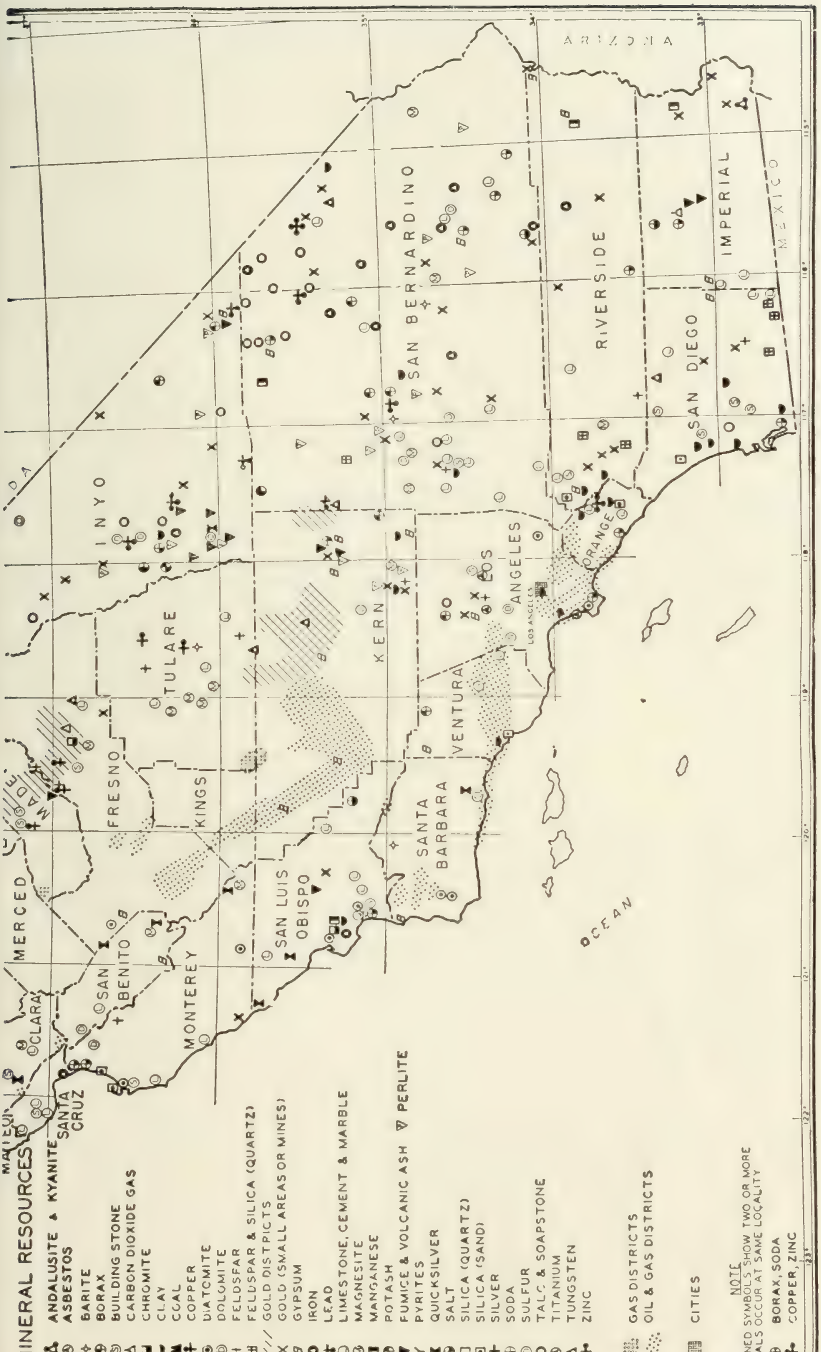
Cypress and Lanning, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles, Sacramento and Redding branch offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are **Bulletins, Special Reports,** and the quarterly **California Journal of Mines and Geology,** issued in January, April, July, and October of each year. **Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of available publications will also be sent free upon request.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
16 0 16 32 48 64 MILES
1948
OREGON
NEVA
MODOC
SISKIYOU
LASSEN
SHASTA
REDDING
DEL NORTE
HUMBOLDT
TRINITY
TEHAMA
PLUMAS
SIERRA
NEVADA
PLACER
EL DORADO
BUTTE
YUBA
SUTTER
GLENN
COLUSA
LAKE
YOLO
MENDOCINO
SONOMA
NAPA
SOLANO
MARIN
SACRAMENTO
SACRA-MENTO
AMADOR
ALPINE
CALAVERAS
TUOLUMNE
MONO
MARIPOSA
SAN JOAQUIN
STANISLAUS
CONTRA COSTA
ALAMEDA
SAN FRANCISCO
SAN
SANTA
PACIFIC


MINERAL RESOURCES
ANDALUSITE & KYANITE
ASBESTOS
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH ▽ PERLITE
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX, SODA
COPPER, ZINC
MATEO
SANTA CRUZ
CLARA
SAN BENITO
MONTEREY
MERCED
MADERA
FRESNO
KINGS
TULARE
INYO
DA
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
ORANGE
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL
ARIZONA
MEXICO
OCEAN
37°
36°
35°
34°
33°
123°
122°
121°
120°
119°
118°
117°
116°
115°

CONTENTS

Page
Annual Report of the State Mineralogist for the 107th Fiscal Year, by Olaf P. Jenkins 301
Mines and Mineral Resources of El Dorado County, California, by William B. Clark and Denton W. Carlson 369
Recommendations for a National Minerals Policy 593
Index to Volume 52 657

PLATES

Plate 9. Geologic map of El Dorado County In pocket
10. Map of western El Dorado County showing mines and mineral deposits In pocket
11. Map of eastern El Dorado County showing mines and mineral deposits In pocket

ANNUAL REPORT OF THE STATE MINERALOGIST CHIEF OF THE DIVISION OF MINES

FOR THE
107TH FISCAL YEAR
JULY 1, 1955 TO JUNE 30, 1956
BY OLAF P. JENKINS *

OUTLINE OF REPORT

Page
Letter of transmittal 302
Summary 303
The mineral wealth of California 305
Administration 308
Financial statement 312
Ore buyers' license and inspection 313
Public information service 313
Public appearances 316
Publications of the Division of Mines 319
Inventories of mining activities 327
State geologic map, 1 : 250,000 327
Geologic quadrangle program 329
North coast geologic guidebook 332
Backlog of completed unpublished reports 332
Library 333
Books added to the Library during fiscal year 1955-56 335
Topographic quadrangle map file 342
Mineral laboratory 342
Mineral exhibits 346
Mineral accessions 346
Mineral commodity program 352
  Bulletin 176 352
  Clay survey 354
  Peat and coal survey 354
  Talc survey 355
  Silica, quartzite, and specialty sands survey 355
  Gypsum and saline survey 356
  Limestone, dolomite, and cement survey 356
  Rock products (crushed rock, sand, and gravel) survey 357
  Nickeliferous laterite survey 357
  Oil and gas surveys 357
Los Angeles branch office 358
Sacramento branch office 360
Redding branch office 361
Cooperation with other state agencies 362
Report of the U. S. Geological Survey on cooperative studies of mineral deposits in California 363

Illustrations

Page
Figure 1. Graph showing relationships of the growth of population in California to the production of minerals 307
2. Index map of California showing progress of the new geologic map of California 328
3. Index map of California, showing progress in detailed geologic mapping on topographic quadrangles 331
4. Photo showing library reference room, south end of Ferry Building 333
5. Graph showing mineral samples identified for the public by the laboratory of the Division of Mines during the last three fiscal years (1952-56) 343
6. Photo showing mineral samples received by the laboratory for identification 344
7. Photo showing visitors to the mineral exhibit 345
8. Graph showing distribution of schoolite sets by the Division of Mines 347
9. Graph showing growth of services in the Los Angeles office of the Division of Mines 359

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* State Mineralogist and Chief of the Division of Mines, Department of Natural Resources.

LETTER OF TRANSMITTAL

Mr. DeWitt Nelson
Director, Department of Natural Resources
Sacramento, California

Sir: I have the honor to transmit herewith for reference to Governor Goodwin J. Knight the annual report of the State Mineralogist, Chief of the Division of Mines, for the 107th fiscal year, July 1, 1955 to June 30, 1956. This is in accordance with the requirement in amended Section 2203 of the Public Resources Code. Sections of the Code are quoted throughout the report to give documentary evidence of what is required of the Division of Mines and to show that the Division's program adhered to the Code.

The first part of the report is devoted to a summary of the activities of the Division of Mines as they are related to the economic development and needs of the State of California. It is shown that although expenditures have been held well in line, and no additions have been made to personnel, the services required of the Division to fulfill demands have increased constantly.

The rapid growth in population of California has caused a very noticeable increase in demands for much-needed raw mineral materials to supply the state's expanding industrial concerns. It is the Division's intention to keep pace with the state's needs and to provide technical information to assist this industrial expansion. Much praise has been received for the unselfish endeavors and fine work of the staff. The people of California appreciate knowing the extent and usefulness of the state's mineral resources. The healthy condition of the state's mineral industry, especially in the development of industrial minerals, speaks for itself. There is no doubt that the Division has had an important and useful part in the economic growth of California, which now may boast of a mineral production which for a period of eight successive years has been valued over one billion dollars for each year; in the last three years this value has been approaching the one and a half billion mark. We recommend, therefore, that continuous healthy support be supplied the Division of Mines and that every encouragement and consideration be given to the development of the mineral resources of California. Few places on this earth are so richly endowed with such a variety of the mineral materials necessary to build a strong foundation for a permanent self-supporting civilization, and we should appreciate and treasure our endowment of this lasting potential wealth.

Respectfully submitted,

Olaf P. Jenkins
State Mineralogist and
Chief of the Division of Mines

Ferry Building, San Francisco
September 1, 1956

SUMMARY

For each of the past 8 successive years the raw mineral materials produced in California have exceeded one billion dollars in value; this value is now approaching the billion and a half mark. If to this amount is added the increased value of manufacturing into useful products, then the state's natural mineral resources should be accredited with several billion dollars more.

In reviewing the activities of the Division of Mines for the past fiscal year, 1955-56, it is apparent that success along every line has been achieved by the Division's services. Efficiency in management is shown by the fact that, during fiscal 1955-56, expenditures of the Division exceeded those of 1954-55 by only 3.6 percent, entirely a reflection of increased costs and wages. A greater number of serious-minded prospectors and industralists have utilized the services and publications of the Division than the previous year, when the information desks were flooded with the questions of the lay public, who for the most part were interested only in finding uranium. That boom came to an abrupt halt, but the general effect was to make people more mineral-minded and appreciative of all the other mineral opportunities the state has to offer.

The rapid increase in the state's population has greatly increased its various industries, especially manufacturing, carried on in California in preference to the East. The establishment of new local industries always results in a demand for local sources of raw materials, usually for various kinds of industrial minerals. Since the function of the Division of Mines is to supply information on minerals, it receives all manner of requests for accurate, authoritative, up-to-date information on the potential resources, occurrences, utilization, grade, value, etc. of the state's mineral deposits, many of which have never before been used or studied. The Division has met this demand and produced valuable information. The Division has found it necessary, however, to start new field projects in mineral commodity surveys and to map the geology of areas which have hitherto been given little attention. In other words, California has entered into a new era of economic growth, requiring new studies and field surveys. Industrial concerns have shown much appreciation of the Division's active assistance in these applied technical studies.

Although mineral fuels (oil and gas) continue to outstrip all other commercial minerals in the state in productive value and abundance, the so-called industrial minerals (largely non-metallics) are now showing the most rapid acceleration in growth. Furthermore, the potential sources for newly desired nonmetallics appear to have a greater and more lasting future than either fuels or metals in California.

The state, however, is still producing gold, silver, lead, zinc, copper, quicksilver, iron, chrome, manganese, and other metalliferous minerals, but attention should now be given also to less-known rare earth metals, and metals such as titanium, which occur in the state, but which are not yet produced. High-grade deposits of precious and other metals may still be mined occasionally at a profit, but these must gradually give place to larger low-grade developments, or to other more profitable minerals. Tungsten is one example, as the state's production records show. Recent surveys by the Division indicate that large nickel reserves occur in the lateritic soils which have been formed on the ancient surfaces of serpentine rocks that cover large areas in California. A change not only in the manner of mining but in the source of materials is exemplified by the extensive use of sea water together with dolomite to produce magnesian products, instead of mining magnesite from the rocks. All these developments are dependent, however, on economic factors, and principally upon markets and sources of products.

Up-to-date information of all sorts on all mineral commodities must constantly be assembled and put into useful form for the public by the staff of the Division. *Mineral Information Service* has proved to be a splendid medium for imparting to the public, without delay, a resumé of much valuable information of current interest. Hundreds of letters from the public indicate that this pamphlet is read and thoroughly appreciated. Nearly 30,000 copies are distributed each month. It has been responsible for announcing the Division's more detailed technical reports. As a result, fiscal year 1955-56 sold far more publications than ever before, i.e. $61,296.23, a figure nearly equal to the entire year's printing fund.

The Division is presently concerned over the fact that many of its most valuable and expensive *Bulletins*, *Journals*, and *Special Reports* are much too soon sold out and there are insufficient funds for reprinting them. It is felt that the annual printing fund should be used for new material in preference to older reports which have already been circulated. This is the case of the Division's largest and most expensive publication, Bulletin 170, *Geology of Southern California*, the first issue (5,000) of which was distributed in a few months. Other publications which have gone out of print cover subjects of mining law, placer mining, county reports, geologic and economic mineral maps, oil geology, California landscape, geologic guidebooks, and mineral commodities. The returns from publication sales are deposited in the general fund, and each year a new printing fund is appropriated. Nearly 2,000 copies of each report are sent gratis to libraries, on exchange, and to cooperating agencies.

The total usefulness of the Division of Mines in the economic development of the state is an intangible factor. It should not be judged only by the *number* of people served, but also by its immediate value to certain industries whose activities have brought much wealth to the state. A single industry helped by the Division may bring into California millions of dolars, whereas thousands of individuals, though they may have become better informed by reason of the services rendered by the Division, cannot be accredited with directly increasing the general wealth of the state. But producing direct wealth is not the only function of the Division; its most general usefulness is found in bringing better understanding and appreciation of the geology and mineral resources of California.

The Division's commodity studies are considered to produce the most results of immediate economic usefulness. Therefore, the Division's forthcoming Bulletin 176, covering a multitude of mineral commodities in 78 chapters, will undoubtedly prove to be of outstanding value to a very large audience. The preparation of this volume has recently occupied a large part of the time of the staff.

Special commodity surveys of more detailed nature are being carried on by the Division, and these have already assisted the development of several important new industries. Particularly significant are the Division's surveys of limestone and raw materials for cement, mineral aggregates, clay, talc, and other minerals for ceramic use, quartzite, and specialty sands, minerals for the soil, like gypsum, minerals for chemical industries, the salines, minerals for insecticide carriers, minerals for paints, for fillers, for filters, and for all manner of industries that manufacture products to meet the demand of the state's rapidly growing population. Certain large industrial plants recently established owe much of their basic encouragement and development to information obtained from the Division: a glass sand plant, a quartzite refractory plant, newly established cement plants, mineral aggregate plants, industries utilizing gypsum and saline minerals, and industries that produce structural products.

If we look about us at the highways, dams, bulidings, equipment, transportation facilities, soil improvement, chemicals, and nearly everything we use, the source of the raw product is most frequently traced back to minerals. The knowledge of these minerals and rocks constitute the study of geology. Basic studies and mapping of geologic formations is, therefore, a continuous program with the Division of Mines. The Division's most helpful cooperative agencies, the United States Geological Survey and the research departments of various institutions of learning and exploration, have contributed many basic geologic maps and reports for publication by the Division, all of which are in constant demand. The Division has accumulated a large backlog of reports and maps not yet published for lack of sufficient printing funds. Progress in industry depends in part on the completion and availability of such maps and reports and the Division is doing all it can to make these useful tools available to everyone.

Since mining and the utilization of minerals for industry is necessarily a continuous and for the most part an accelerating process, to go on as long as there is a California, it behooves us to see that our children take up the work where we leave off. It is a great satisfaction, therefore, to us that we get many letters of appreciation from grammar school children who have enjoyed studying the mineral collections provided them by the Division. It is also a great satisfaction to see the enthusiasm and interest of the school children of all ages who are frequently brought through the Ferry Building to visit our fine exhibits and mineral collections. Last year 30,910 persons visited the exhibits, 5,935 of whom were children. Here, however, vast improvement should be made by providing the exhibits with a full time technical custodian and by adding to the colection (if additional space is made available) more industrial exhibits to show how minerals are used in the manufacture of various products. During last year a total of 77 fine new mineral specimens were donated to the exhibits. If space were available, expensive industrial exhibits would also be donated by industries.

Persons seeking information may bring mineral specimens to the Division for identification. During the fiscal year 1955-56 the Division's laboratory identified 5,935 samples submitted by the public, and presented 499 sets of California minerals to the schools for study. The laboratory also serves the Division's staff in research assignments.

Not everyone realizes the invaluable assistance the Division's library gives to miners, engineers, scientists, and the lay public in providing basic information on geology, mineralogy, mining, metallurgy, chemistry, mining history, and all allied subjects. It serves constantly both the public and the members of the staff. Many donations of books are made to the library. This year 510 books were added to the collection of over 10,000. The public and the Division's staff consulted more than 17,000 items during the year.

There are so many projects being carried on in California by federal and state surveys on mining, exploration, geology, engineering, water development, and recreation, that the Division of Mines finds it mutually advantageous to carry on cooperative programs of work with these agencies. In particular, the mineral production records are a result of cooperation with the U. S. Bureau of Mines. To this Annual Report is attached the report of the cooperative program with the Mineral Deposits Branch of the U. S. Geological Survey. The list of backlog reports and the list of geologic quadrangle reports include many projects of cooperation with university departments as well as with the federal survey. The new State Geologic Map, scale 1:250,000, is currently being compiled with data (both published and unpublished) from hundreds of sources.

There are any number of ways and instances where the Division of Mines finds opportunities to be helpful, but first of all it must be informed itself; therefore, it must necessarily carry on surveys and investigations all over the state on all manner of problems,—basic science, economic problems, engineering enterprises, educational assistance, and a host of other subjects.

THE MINERAL WEALTH OF CALIFORNIA

Public Resources Code:

"2205. The State Mineralogist shall:

"(a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.

"(b) Collect statistics concerning the occurrence and production of the economically important minerals and the methods pursued in making their valuable constituents available for commercial use.

"2207. The owner, lessor, lessee, agent, manager, or other person in charge of any mine of whatever kind or character within the State shall forward to the State Mineralogist, upon his request, at his office, not later than the thirty-first day of March in each year, upon forms which will be furnished, a report showing the character of the mine, the method of working the mine and the general condition thereof, and the total mineral production for the preceding calendar year. Any such person who fails to comply with the provisions of this section is guilty of a misdemeanor.

"Such reports shall be confidential. Other records are public records unless excepted by statute. Statistical bulletins based on these reports and published under the provisions of Section 2205 of this code shall be compiled to show, for the State as a whole and separately for each county, the total of each mineral produced therein, provided that, in order not to disclose the production of any operator, no production figure shall be published which represents the production of less than three operators; and when such production figure for any county would conflict with such provision it may be combined with such production figures for one or more other counties. Such bulletins shall be published annually by June 30th or as soon thereafter as practical."

The need for the technical services of the Division of Mines continues to expand along with the constant growth of mineral production in California, which has made long strides during the war and post-war period (1940-55). During that time the value of production has increased from a pre-war low of $343,000,000 in 1940 to a post-war high of $1,447,000,000 (preliminary estimate) in 1955. The annual value of mineral production in California has exceeded one billion dollars for 8 consecutive years, 1948-55. This continued growth in the quantity and value of mineral production in the state closely parallels the growth of population and manufacturing industries. Constant demand

California mineral production in 1954.

The fourth consecutive year during which California mineral production attained an all-time high was reached in 1954. Production totaled $1,420,859,399, as compiled by the U. S. Bureau of Mines in cooperation with the California Division of Mines. This figure was an increase of 2 percent over the 1953 production valued at $1,392,829,025 (final).

Mineral commodity	Quantity		Value
Boron minerals	790,449	short tons	$26,714,440
Cement	32,707,374	barrels	98,169,729
Chromite ore and concentrates	30,661	short tons	2,285,250
Clay (raw)	1,814,420	short tons	5,120,654
Copper	724,000	pounds	213,580
Gem stones			100,000
Gold	237,886	fine ounces	8,326,010
Gypsum	1,161,502	short tons	2,803,862
Iron ore	1,270,292	long tons	*
Lead	5,342,000	pounds	731,854
Lime	212,386	short tons	3,387,981
Magnesium compounds	40,969	short tons	2,715,689
Manganese ore and concentrates over 35% Mn	8,513	long tons	617,284
Manganese ore and concentrates under 35% Mn	25,190	long tons	926,675
Marl	5,464	short tons	21,965
Mercury	11,262	flasks	2,977,560
Natural gas	507,289,000	M cubic feet	104,502,000
Natural gas liquids	30,411,000	barrels	104,673,000
Perlite (crude)	14,811	short tons	103,148
Petroleum	355,779,000	barrels	902,897,952
Pumice and volcanic ash	70,964	short tons	421,208
Salt	1,185,844	short tons	6,126,194
Sand and gravel	70,492,356	short tons	67,847,806
Silver	309,575	fine ounces	280,181
Stone (miscellaneous)	14,096,582	short tons	23,126,345
Talc, soapstone, pyrophyllite	133,474	short tons	1,211,201
Tungsten concentrates	3,089	short tons	13,209,747
Volcanic cinders	495,700	short tons	230,430
Zinc	2,830,000	pounds	305,640
Unapportioned*			40,812,014
Total value for 1954			$1,420,859,399
Estimate for 1955			$1,447,000,000

* Includes asbestos, barite, bromine, calcium chloride, carbon dioxide, coal (lignite), diatomite, feldspar, garnet, ilmenite, iodine, iron ore, lithium compounds, magnesite, molybdenum, peat, platinum, potassium salts, pyrite, quartz, rare earth concentrates, sand and sandstone (ground), slate, sodium carbonate and sulfate, sulfur, strontium minerals.

by industry for new and useful minerals, and the desire for information concerning the state's resources, require the Division of Mines to keep alert and ready to serve.

Total annual value of California's mineral production.
1947-1955

1955	$1,447,456,500 (estimated)	1950	1,056,047,000
1954	1,420,859,000	1949	1,074,416,000
1953	1,392,829,000	1948	1,146,411,000
1952	1,214,870,000		
1951	1,209,428,000	1947	$859,039,000

During 1954, the latest year for which complete data are available, the value of mineral production totaled $1,420,859,359, an all-time high. Petroleum led all commodities in value of production, followed by natural gas liquids, natural gas, cement, sand and gravel, boron minerals, stone, tungsten ore and concentrates, iron ore, gold, salt, and clay.

Although petroleum products headed the list in value of production, they declined from the high points in quantity and value reached during the previous year (1953).

Materials of construction made the next largest contribution to the total production of the state. Cement, sand and gravel, and stone reached all-time highs in quantity and value of production during 1954; value of the clay produced reached an all-time high; but the value of lime and gypsum produced was slightly less than in the previous year.

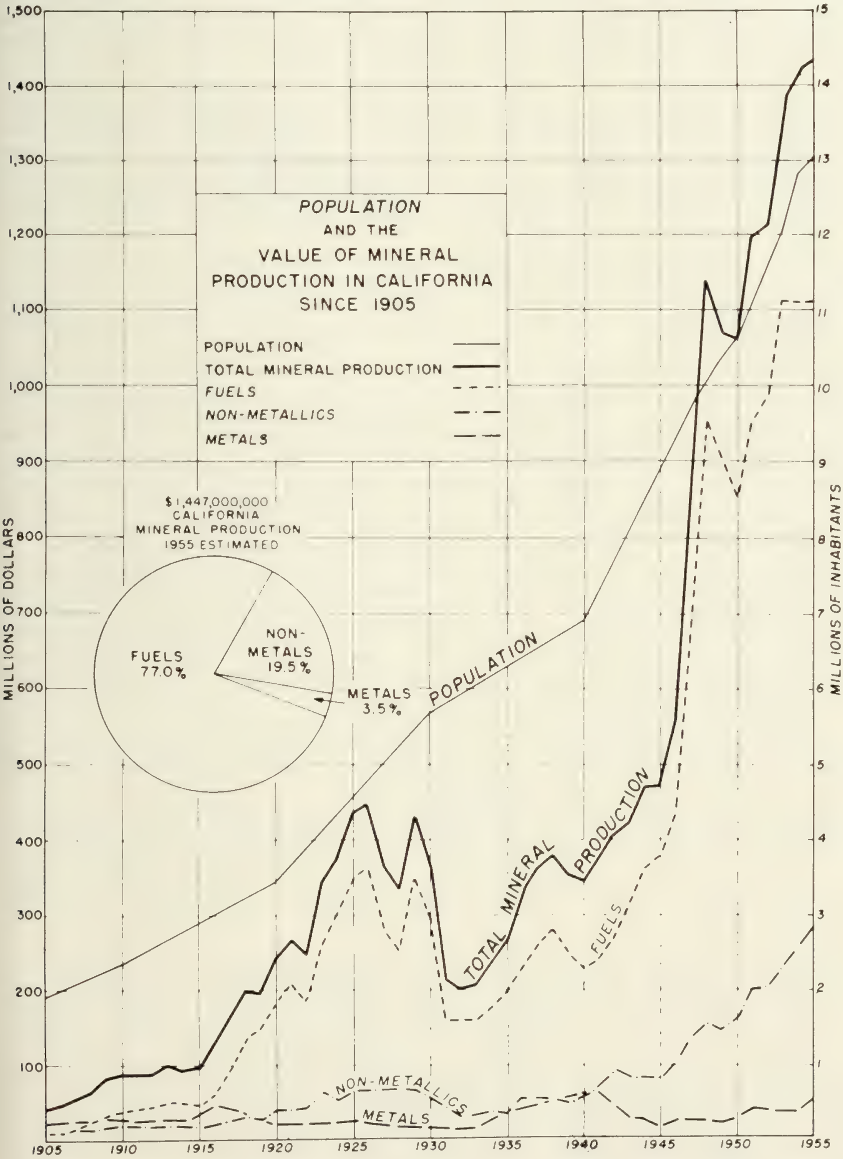

FIGURE 1. Graph showing relationships of the growth of population in California to the production of minerals. Recent acceleration in the nonmetallic industries is shown to be greater than either mineral fuels or metals.

The value of saline production, an important segment of the mineral industry, increased during 1954. Boron minerals, potash, and soda salts all registered increases in quantity and value over the previous year. Salt and magnesium compounds registered a decline over the same period.

The production of metallic minerals increased during 1954. The value of tungsten ore and concentrates reached an all-time high. Substantial increases in value were shown also by mercury and manganese ore and concentrates. Smaller increases were registered by chromite and gold. Declines in value were reported for iron ore, silver, copper, lead, and zinc.

ADMINISTRATION

Public Resources Code:

"2201. The State Mineralogist shall employ competent geologists, field assistants, qualified specialists, and office employees when necessary in the execution of the plans and operations of the division under this chapter.

"2202. The State Mineralogist shall maintain offices, and a museum, library, and laboratory in San Francisco for the purposes provided in this chapter.

"2205. The State Mineralogist shall:

"(a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.

"(g) Maintain, in effect, a bureau of information concerning the mineral industry of the State . . ."

Public Resources Code:

"507.1. State Mining Board: Members: Appointment: Qualifications: Incumbent members: Filling vacancies: Confirmation of appointments: Organization: Powers: Appointment of employees of Division of Mines. There shall be a State Mining Board, consisting of five members appointed by the Governor with the advice and consent of the Senate for terms of four years and until their successors are appointed and qualified. Members shall be selected from those citizens of this State associated with or having detailed knowledge of the prospecting for, production, processing or marketing of the minerals of this State.

"The members of the incumbent Mining Board, continued in office, shall be classified by the Governor so that the terms of office of one member shall expire January 15, 1950, and the terms of two members on January 15, 1951, and January 15, 1952, respectively. An appointment to fill a vacancy occurring before the expiration of a term shall be only for the remainder of that term. All appointments made when the Legislature is not in session shall be subject to confirmation at the next regular or special session of the Legislature. The board shall have power to organize itself and select its officers.

"The board shall represent the State's interest in the development, utilization and conservation of the mineral resources of the State. It is empowered to establish policies conforming to the provisions of state statutes to govern the administration of the Division of Mines.

"The director may authorize the State Mineralogist to exercise his power to appoint employees of the Division of Mines in accordance with the State Civil Service Act. The director may authorize the State Mineralogist or any employee of the Division of Mines to exercise any power granted or perform any duty imposed upon the director by the State Civil Service Act. (Added by Stats. 1949, Ch. 1081, Sec. 2.)"

The Division of Mines is one of several divisions in the Department of Natural Resources. Headquarters of the Department and its Director are in Sacramento. The State Mining Board, consisting of five members appointed by the Governor, and serving without compensation, advises the Director on mining matters and policies. Headquarters of the Division and its Chief, the State Mineralogist, are in the south wing of the Ferry Building, San Francisco. The Chief and all other personnel enjoy the privileges of State Civil Service. The Division maintains three branch offices, the largest in Los Angeles and smaller ones in Sacramento and Redding, which extend the services of the Division directly to the public in those areas. Each office carries on the various services and activities of the Division, except that Administration, Editorial, Drafting, Library, and Laboratory are centered in the headquarters office in San Francisco. The chief, Olaf P. Jenkins, is assisted in administration and operation of the Division by the Deputy Chief, Gordon B. Oakeshott.

During 1956, reorganization of Division administration and supervision took place to recognize four major phases or areas of Division work, each supervised by a Senior Mining Geologist:

MINING ENGINEERING, inventory of mineral resources by counties, mineral utilization surveys, and management of Division business—supervised by Richard M. Stewart.

TECHNICAL INFORMATION SERVICES, mining activities, mineral economics and statistics, and library—supervised by Fenelon F. Davis.

MINERALOGY, PETROLOGY, LABORATORY, AND EXHIBITS—supervised by Charles W. Chesterman.

GEOLOGIC AND COMMODITY SURVEYS, quadrangle and state mapping—supervised by Oliver E. Bowen, Jr.

At Los Angeles, Sacramento, and Redding are the branch offices which carry on the phases of Division work most effective and most needed in their respective parts of the state. Los Angeles, the largest, is headed by Supervising Mining Geologists Lauren A. Wright, Sacramento by Associate Mining Geologist William B. Clark, and Redding by District Mining Engineer John C. O'Brien.

In July 1956 the Division of Mines staff comprised 56 employees—33 technical geologists and engineers, and 23 stenographic and other nontechnical employees. Technical positions of the Division of Mines are distinguished in state service by the classification of Mining Geologist: Supervising, Senior, Associate, Assistant, and Junior.

The Editorial section, which processes technical manuscripts for publication, is supervised by Public Information Officer Elisabeth L. Egenhoff. The Drafting section, headed by Supervising Geological Draftsman Richard A. Crippen, Jr., prepares charts, maps, and illustrations for the publications. Librarian William A. Sansburn is in charge of the Division's technical library which serves the public at the San Francisco headquarters office and also distributes sets of Division publications to public school teachers and students, and maintains a film lending library on the mineral industry.

A list of the technical staff of the Division of Mines as of July, 1956, with the major assignments and interests of each, follows:

SAN FRANCISCO HEADQUARTERS OFFICE

Olaf P. Jenkins, Chief, Division of Mines (State Mineralogist) Division administration.

Gordon B. Oakeshott, Deputy Chief, Division of Mines; Division supervision; preparation of a bulletin on geology and mineral resources of San Fernando quadrangle; diatomite, graphite, petroleum; earthquakes and active faults.

Richard M. Stewart, Supervision mining engineering section and Division business; county inventory reports; mineral utilization surveys; San Diego County; Anza-Borrego State Park; tungsten.

Charles W. Chesterman, Supervision mineralogy petrology section, laboratory, and exhibits; preparation of a bulletin on geology and mineral resources of Matterhorn Peak quadrangle; pumice, perlite, and obsidian; jade; fluorspar, cobalt.

California counties in order of total value of recorded mineral production to and including 1954.

County	Year of first recorded output	Rank, value of output in 1954	Value of total recorded output	1954 value of output	Principal minerals in order of value for 1954
Los Angeles	1880	1	$5,445,347,999	$325,164,842	Petroleum, natural gas liquids, sand and gravel, natural gas, stone.
Kern	1880	2	4,325,111,118	302,533,594	Petroleum, natural gas liquids, natural gas, boron minerals, cement.
Orange	1889	4	1,763,056,965	118,842,752	Petroleum, natural gas liquids, natural gas, sand and gravel, iodine.
Fresno	1880	5	1,613,899,803	115,192,747	Petroleum, natural gas liquids, natural gas, sand and gravel, stone.
Ventura	1880	3	1,487,013,326	170,076,915	Petroleum, natural gas, natural gas liquids, sand and gravel, stone.
Santa Barbara	1881	6	955,743,059	92,815,576	Petroleum, diatomite, natural gas liquids, natural gas, sand and gravel.
San Bernardino	1880	7	879,537,844	67,427,332	Cement, boron minerals, sodium carbonate, potassium, sand and gravel.
Kings	1894	11	457,684,694	18,418,566	Petroleum, natural gas, natural gas liquids, gypsum, sand and gravel.
Sacramento	1880	12	306,949,099	18,028,904	Natural gas, sand and gravel, gold, clay, platinum, silver.
Riverside	1891	8	280,228,138	28,138,422	Iron ore, cement, stone, clay, sand and gravel, gypsum, manganese ore.
Santa Clara	1850	9	266,247,856	23,271,503	Cement, stone, sand and gravel, mercury, clay, magnesite, chromite.
Nevada	1880	28	[1]265,169,579	2,134,511	Gold, sand and gravel, silver, stone, tungsten concentrates, copper.
Shasta	1880	33	224,091,916	1,580,233	Pyrites, sand and gravel, stone.
Inyo	1880	15	217,830,347	10,493,046	Tungsten concentrates, lead, sodium carbonate.
Alameda	1890	14	198,250,368	12,047,155	Salt, sand and gravel, magnesium compounds.
Calaveras	1880	16	179,198,595	8,454,643	Cement, stone, sand and gravel, clay.
Amador	1880	46	159,934,473	622,007	Clay, copper, coal, gold.
Solano	1873	18	151,613,981	6,711,341	Natural gas, clay, stone.
Santa Cruz	1894	20	140,748,246	6,104,761	Cement, sand and gravel, stone.
Yuba	1880	25	129,944,567	2,611,997	Gold, sand and gravel, clay, platinum.
San Mateo	1895	17	115,154,700	7,741,105	Cement, stone, sand and gravel.
Monterey	1889	10	101,285,268	20,527,665	Petroleum, sand and gravel, lime, stone.
San Benito	1865	21	89,640,628	4,824,902	Cement, mercury, stone, petroleum.
Butte	1880	27	89,224,837	2,175,791	Sand and gravel, natural gas, stone.
Contra Costa	1894	30	88,844,676	1,991,061	Stone, sand and gravel, natural gas, clay.
Plumas	1880	55	83,112,212	111,095	Sand and gravel, gold, stone, chromite.
San Luis Obispo	1876	13	82,241,309	12,673,450	Petroleum, natural gas liquids, chromite, sand and gravel.
San Diego	1880	19	74,395,061	6,206,399	Sand and gravel, stone, salt, magnesium compounds, tungsten concentrates.
Placer	1880	51	64,848,584	440,655	Clay, sand and gravel, stone, gold.
Tuolumne	1880	41	63,138,676	885,306	Lime, stone, tungsten concentrates, chromite.
El Dorado	1880	32	58,963,963	1,831,058	Stone, lime, gold, slate, sand and gravel, soapstone, chromite, copper.
Siskiyou	1880	36	58,714,200	1,354,579	Sand and gravel, gold, chromite, stone, volcanic cinder.
Sierra	1880	47	57,963,817	568,097	Gold, sand and gravel, silver, stone.
San Joaquin	1885	22	52,867,473	2,964,968	Sand and gravel, natural gas, manganese ore, clay.
Trinity	1875	52	51,428,357	402,764	Gold, sand and gravel, stone, chromite.
Napa	1862	40	49,909,635	1,073,640	Stone, chromite, sand and gravel.
Mono	1880	23	40,403,175	2,952,678	Tungsten concentrates, sand and gravel, pumice.
Merced	1880	42	35,606,618	860,097	Sand and gravel, gypsum, gold.
Mariposa	1880	56	33,508,067	104,366	Sand and gravel, gold, tungsten concentrates.
Sonoma	1873	26	33,465,768	2,528,480	Sand and gravel, mercury, stone.
Tulare	1880	29	28,887,425	2,129,587	Natural gas, tungsten concentrates, sand and and gravel.
Imperial	1907	24	27,183,405	2,932,274	Gypsum, sand and gravel, manganese ore, tungsten concentrates, pumice, clay.
Stanislaus	1880	45	26,413,028	655,872	Sand and gravel, manganese ore, clay.
Madera	1893	31	24,252,593	1,967,257	Tungsten concentrates, natural gas, sand and gravel.
Lake	1873	43	23,078,949	770,993	Mercury, sand and gravel, chromite.
Marin	1888	38	21,506,204	1,277,141	Stone, sand and gravel, clay.
Humboldt	1880	39	18,774,294	1,098,363	Sand and gravel, natural gas, stone.
Yolo	1873	35	10,398,739	1,482,615	Sand and gravel, natural gas.
Del Norte	1880	37	9,342,736	1,349,774	Stone, sand and gravel, chromite.
San Francisco	1894	58	8,732,350	0	Stone, gold, silver (last output).
Glenn	1893	49	[2]6,345,395	478,547	Sand and gravel, natural gas, chromite.
Mendocino	1880	44	[3]5,773,779	686,989	Sand and gravel, stone, carbon dioxide.

California counties in order of total value of recorded mineral production to and including 1954—Continued.

County	Year of first recorded output	Rank, value of output in 1954	Value of total recorded output	1954 value of output	Principal minerals in order of value for 1954
Colusa	1875	57	4,853,719	88,409	Sand and gravel, chromite, natural gas.
Lassen	1880	54	3,524,844	195,198	Stone, sand and gravel, volcanic cinders.
Modoc	1880	50	3,436,802	445,772	Sand and gravel, stone, pumice.
Alpine	1880	34	[1]2,851,025	1,572,363	Sulfur, tungsten concentrates, sand and gravel.
Tehama	1880	48	[2]2,717,422	[2]505,889	Sand and gravel, natural gas, chromite.
Sutter	1908	53	2,424,113	279,824	Natural gas, clay, sand and gravel.
Total recorded value by counties—1850-1954 inclusive			$21,002,825,819		
1954 total value				$1,420,859,399	

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[1] Total recorded production through 1946; 1947-49 output of Alpine County included with Nevada County.

[2] Total recorded production through 1946; 1947-49 output of Tehama County included with Glenn County; 1951 output combined with Lake County.

[3] Total recorded production through 1946; 1947-49 output of San Francisco County included with Mendocino County.

Oliver E. Bowen, Jr., Supervision geologic and commodity surveys; Mariposa County; Cherokee hydraulic pit; cement, limestone and dolomite.

Fenelon F. Davis, Supervision technical information services; manganese and mercury; mining operations.

Henry H. Symons, Mineral economics and statistics; mining operations; technical information services.

Elisabeth L. Egenhoff, Supervision of editorial section; technical editing; early history of mineral discovery and operations.

Mary H. Rice, Technical editing; early history of mineral discovery and operations; photography.

Richard A. Crippen, Jr., Supervision of drafting section; preparation of drafted illustrations.

William A. Sansburn, Library.

George L. Gary, Ore buyers' inspection; mineral exhibits.

Charles W. Jennings, Compilation of revision of State geologic map; coal and peat; Vallecitos bentonite; preparation of a bulletin on geology and mineral resources of Hernandez Valley quadrangle.

William E. Ver Planck, salines, gypsum, borates; silica resources, completion of a bulletin on salt in California.

Salem J. Rice, Report on reconnaissance geology of coastal area north of Eureka; serpentine and associated asbestos, chromite, and nickel.

J. Grant Goodwin, Tulare County; State economic map of lead-zinc deposits; cadmium and minor metals; arsenic; silver.

Melvin C. Stinson, Uranium and rare-earth minerals; vanadium; uranium in Plumas County; massive sulfides.

Earl W. Hart, Petroleum and natural gas; data on dry holes; offshore oil.

Harold B. Goldman, Rock, sand and gravel; carbon dioxide, antimony; Alameda and Contra Costa counties.

Edmund W. Kiessling, Petroleum and natural gas; data on dry holes; offshore oil.

Frederic R. Kelley, Clay and ceramic materials in northern California; Cretaceous stratigraphy of part of the southern Diablo Range.

F. Harold Weber, Technical information and laboratory services; San Diego County.

Rudolph Strand, Technical information and laboratory services.

James B. Koenig, Technical information and laboratory services.

Robert A. Matthews, Laboratory and mineral exhibits.

LOS ANGELES OFFICE

Lauren A. Wright, Supervision; preparation bulletin on the mineral commodities of California; beryllium, calcite, feldspar, gemstones, kyanite, mica, pyrophyllite, talc; geology and mineral deposits of southern Death Valley.

Thomas E. Gay, Jr., Kern County report; ferro alloys, iron, rock, sand and gravel; geology of Coffee Creek area in Klamath Mountains.

Bennie W. Troxel, Kern and Imperial counties; abrasives, thorium, uranium in southern California, wollastonite; geology of Shadow Mountains.

Cliffton H. Gray, Jr., Geology of Corona quadrangle; dolomite, limestone, and tin; Orange County.

George B. Cleveland, Clay and ceramic materials; lateritic nickel in Sierran foothills; biogeochemical prospecting.

SACRAMENTO OFFICE

William B. Clark, Supervision; El Dorado and Calaveras counties; gold and platinum; mining operations of the Alleghany district and of the Sierra Nevada.

Philip A. Lydon, Calaveras County; geology of part of Mt. Abbott quadrangle in the Sierra Nevada; sulfur, titanium.

REDDING OFFICE

J. C. O'Brien, Trinity and Shasta counties; copper and zinc; mining operations of the northern counties.

FINANCIAL STATEMENT

The following statement of expenditures for the fiscal year 1955-56 is approximate inasmuch as all bills for the year are not available for payment. A comparison of these approximate total expenditures with the actual total for 1954-55 shows a 3.6 percent increase:

Expenditures 1954-55	$471,613
Expenditures 1955-56 (approx.)	$488,761

This relatively small increase reflects the increased costs of equipment, supplies, services, and wages. The growing population in the state demands each year greater services from the Division of Mines than any previous year. The Division, however, rendered these services in 1954-55 without any additions to the staff over the previous fiscal year.

*Expenditures during fiscal 1955-56 *.*

Total salaries and wages		$291,537.34
Operating expenses:		
Freight, cartage and express	$1,692.54	
Telephone and telegraph	2,653.07	
Toll calls	414.60	
Light, heat, power	2,310.57	
Rent of building space	31,052.40	
Repairs and maintenance	402.71	
Office supplies and services	4,659.17	
Postage	10,703.13	
Photography supplies and services	989.97	
Blueprinting	667.19	
Printing bulletins and maps	63,168.52	
Printing, general	1,397.40	
Technical reports	6,700.00	
Auto operations—parts, services, gas, oil, tires, tubes	6,207.28	
Travel	15,324.47	
Auto mileage	475.95	
Laboratory supplies and services	3,114.90	
Premiums on bonds	124.34	
Library supplies and services	916.60	
Exhibits supplies and services	245.95	
Total operating expenses		$153,220.76

* Some of the figures given are approximate, because not all bills for the fiscal year were paid at the time this report was prepared.

Equipment:		
Automobile	$5,071.63	
Field	668.35	
Office	461.36	
Miscellaneous replacements	99.33	
Miscellaneous additional	1,227.38	
Library	1,474.57	
Total equipment		$9,002.62
Total expenditures		$453,760.72
Special item: Geological exploration in cooperation with U. S. Geological Survey		$35,000.00
Grand total		$488,760.72

ORE BUYERS' LICENSES AND INSPECTION

Public Resources Code:

"2250. It is unlawful for any person to engage in the business of milling, sampling, concentrating, reducing, refining, purchasing, or receiving for sale, ores, concentrates, or amalgams bearing gold or silver, gold dust, gold or silver bullion, nuggets, or specimens without first procuring the license provided for by this chapter.

"2253. The application for a license to carry on such business shall be made to the State Mineralogist. . . .

"2267. Every licensee under this chapter shall file monthly with the State Mineralogist a report of all purchases made under this chapter. The reports shall be made upon forms prescribed by the State Mineralogist and shall contain the information required by this chapter."

Sixty-one ore buyers' licenses were issued by the Division of Mines during the fiscal year. Thirty-one licenses were limited (limiting buyer to $1,000 in purchases during the calendar year), and 30 licenses were unlimited (without limit on purchases). Sixty-four licenses were issued by the Division during the previous fiscal year.

All licensees' records and transactions were inspected and checked to insure compliance with the law. Cooperation with local, state, and federal agencies in the investigation of suspected illegal transactions and illicit traffic in gold continued during the year.

The "Ore Buyers' License Act" was reprinted in March 1956, deleting the repealed sections and adding the amended ones.

PUBLIC INFORMATION SERVICE

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a museum, library, and laboratory in San Francisco for the purposes provided in this chapter.

"2205. The State Mineralogist shall:

". . . (g) Maintain, in effect, a bureau of information concerning the mineral industry of this State. . . ."

Any well-planned mineral investigation begins with office research. This generally includes a review of the published literature on the subject, a study of the topographic and geologic maps involved, and consulation with individuals whose knowledge and experience may provide valuable information. Since few individuals or organizations in California are equipped with all these facilities or have the time or personnel to render services, the offices of the Division of Mines are frequently first contacted and invariably much valuable assistance is received as a result.

The Division maintains an information desk in each of its offices: San Francisco, Los Angeles, Sacramento, and Redding. Its headquarters office in San Francisco maintains the most complete facilities, including Library, Exhibits, and Laboratory. At the information desk visitors may obtain and purchase maps and publications of the Division or leave specimens to be identified in the Laboratory. Often preliminary discussion with a member of the technical staff may result in solving a particular problem. Each member specializes in certain mineral commodities and is capable of providing much valuable information. If a review of literature or maps is needed, the visitor is directed to the Division's large technical Library, where he is given personal assistance by the Division's Librarian.

The following statements are typical examples of services rendered by staff members during fiscal year 1955-56; many of these services resulted in establishing new industries in California and greatly increasing the state's mineral wealth.

Basic Geologic Data. Furnished lists of topographic and geologic maps to engineers of two large mining companies. Discussed geology of a potential oil area with Navy representatives. Discussed geology and exploratory wells in San Luis Obispo County with an oil company geologist. Supplied information to State Chamber of Commerce on possible offshore petroleum development. Discussed fault problem with a telephone company geologist. Advised state highway attorney regarding mineral possibilities along a right of way. Directed a consulting mining engineer to source data for San Simeon area. Assisted research geologist with information on distribution of Cretaceous rocks in California. Assisted company geologists with information from state map. Gave geologic information to a gas company on Capay Valley and Mono Lake area. Gave geologic data on San Mateo County to oil and mining companies and to State Division of Beaches and Parks. Outlined potential nickeliferous areas to mining company geologist. Assisted a company in setting up an exploration program for uranium. Supplied a flood control geologist with maps and geologic references on stone.

Raw Materials Sources. Supplied research director of a steel company with detailed data on perlite deposits. Furnished data on volcanic rock suitable for roofing granules to president of a rock wool manufacturing company. Discussed salt resources of southern California with a salt consumer in Nevada. Supplied information on gypsum which provided a basis for sale of a property to a large corporation. Directed rock products company to a source of roofing granules. Furnished a steel company with sources of high-silica gravels in northern California. Supplied a construction company with sources of rip-rap. Located sources of tremolite asbestos for two manufacturing companies. Helped Batelle Institute in search for commerical talc for eastern consumer. Assisted a ceramic company in locating a deposit of quartzite which they later purchased and developed. Suggested areas for prospecting for uranium with airborne equipment. Discussed problems of obtaining garnet for impact abrasive purposes. Assisted a mineral company official with information on location of high calcium limestone deposits. Assisted a railroad geologist with location of serpentine and limestone deposits in a specific locality. Provided data on limestone deposits to two cement companies interested in establishing new plants. Assisted a linoleum manufacturer in locating a source of clay for filler which will cost less than imported clay. Helped producer of agricultural minerals to locate deposits of minerals high in potassium. Provided consulting mining engineers with data on expansible shale resources. Assisted county officials in selecting minerals for exhibition at State Fair.

Production Data and Mineral Processing. Assisted a tungsten-mill operator in correcting his mill flow sheet to upgrade scheelite concentrate. Advised two quicksilver producers on the possible economic application of hydrometallurgy to quicksilver recovery. Supplied General Services Administration with data on operating tungsten mines. Assisted U. S. Bureau of Mines with information on tungsten, manganese, mercury, and other economic minerals. Furnished data on salt to Stanford Research Institute. Provided information and references on titanium recovery to an investor. Furnished statistical and related data to rock and gravel producers for a survey of reserves. Informed owner of magnesite and silica deposits of specifications and market conditions. Provided information on metallurgy of gold and silver to potential producer. Demonstrated to a producing company that a valuable by-product clay was being wasted. Supplied consulting geologist with information on by-product sulfur. Supplied data on beach sands to a potential operator. Discussed measurement of ore reserves and mine evaluation with a consulting mining engineer. Furnished mine data to U. S. engineers on Trinity River project. Supplied owner of patented gold-dredging land with list of active dredging companies. Supplied mine data to official studying water pollution of streams.

Physical and Chemical Data on Rocks and Minerals. Supplied information on a sand and gravel deposit for a potential producer and determined presence of potentially reactive ingredients. Furnished information on testing procedures in rock products industries to equipment-manufacturing concern. Supplied a paving company with information on type of sand and gravel encountered in specific localities. Assisted a testing laboratory in setting up a colorimetric method of making quantitative tungsten assays. Provided petrographic data on granites to surface plate manufacturer. Interpreted assay reports for prospectors and property owners. Helped prospectors with mineral identification problems. Discussed prospects of opening an assay laboratory with an assayer looking for a location.

Marketing Data and Mineral Utilization. Gave information on geology and markets to a pumicite producer. Provided a company official with marketing data on perlite. Informed owners of volcanic ash and caliche deposits on economics of the deposits and possible markets. Provided information on current market situation to operator of a feldspar mine. Supplied data on specialty sand deposits and markets to a group making an economic survey of sand. Provided marketing data to owner of an iron deposit. Discussed basic problems of nonmetallic minerals with a businessman interested in entering this field. Discussed sulfuric acid market with manager of an engineering company.

Mining Documents and Law. Assisted a claimholder with information regarding his rights under the new mining law. Assisted company representative with information on leasing and royalty payments on various minerals. Discussed sources of information on mining claims with a mining engineer. Discussed method of locating a limestone deposit with a consulting geologist. Helped prospectors in filling out location notices and affidavits of labor.

Miscellaneous Services. Assisted and advised in set-up of Cub Scout rock show at Scoutorama. Provided Department of Fish and Game with a map showing boundaries of proposed Saline Valley withdrawal. Supplied State Senate committee with mining maps and publications. Addressed numerous gem and mineral societies on the geology in their locality; led other geologic groups on field trips. Assisted Administration in arranging the Western Governors Mineral Policies Conference at Sacramento. Assisted in compilation of mineral policy recommendation at the Conference. Supplied data on mineral resources of various counties as basis for talks by the Administration. Assisted a consulting geologist with information on prospecting for aggregate suitable for concrete. Assisted university students in selecting Ph. D. problems for advanced study. Prepared and delivered short radio talks on economic minerals for broadcasting company. Talked to Structural Engineers Association on active earthquake faults. Served on councilling panel for high school students interested in geology and mining. Edited a manuscript for an author of a book on California minerals. Advised chairman of a state college geology department on planning of curriculum. Discussed with a writer the plot and background for mining movie. Furnished lists of operating mines to machinery salesmen and miners seeking employment. Suggested names of consulting engineers to assist Bureau of Reclamation Trinity River project.

PUBLIC APPEARANCES

Frequently the Division of Mines is requested to supply a speaker on the geology or mineral resources of California, to conduct a field trip through an area of particular interest, to show technical motion pictures from the Division's film library, or to provide publications for display and sale. During the 1955-56 fiscal year, members of the staff attended and participated in a total of 154 meetings, conferences, fairs, and mineral shows. Thirty-six talks were given and four separate field trips were conducted. Display of Division of Mines publications was requested at meetings of technical societies, fairs, and mineral shows; during 16 of these, publications were sold in the amount of $2,050.83. The following list indicates the type and variety of public appearances during the year.

Technical and Advisory

American Association of Petroleum Geologists—Attended technical sessions of 1955 annual meeting; chairman of one section; maintained information book; sold publications. Attended technical sessions of National Convention in Chicago and provided a display of maps. Attended meetings and lectures of Pacific Section throughout the year.

American Institute of Mining, Metallurgical, and Petroleum Engineers—Served as chairman of Mining Branch, Southern California Section. Attended monthly meetings. Served on program committee of the San Francisco section.

American Mining Congress—Served on program committee for annual meeting, and attended technical sessions.

American Petroleum Institute—Wrote article on California petroleum for special convention issue of Oil Forum; attended technical sessions.

Association of American State Geologists—Served as Vice-President. Attended technical sessions of 1956 annual meeting in Kentucky.

California State Chamber of Commerce—Participated in planning of industrial Plant Location Committee.

Geological Society of America—Attended technical sessions of annual meeting and presented papers.

Los Angeles Chamber of Commerce Mining Committee—Attended meetings and uranium conference.

Mining Association of Southern California—Attended meetings.

California State Mining Board—Staff members presented a panel discussion of mineral resources and industry at the Riverside meeting. Staff members participated in discussion of Ione Valley dam site at the Los Angeles meeting.

Mining Association of Southwest—Attended meetings.

San Francisco Chamber of Commerce Mining Committee—Attended meetings; participated in Chemical Industry Committee.

Sacramento Chamber of Commerce—Presented illustrated talk on active mines and mineral industry in Sacramento area.

Society of Economic Paleontologists & Mineralogists—Attended lecture and field trip.

Western Governors Mineral Policies Conference—Entire technical staff participated. Served as section managers for commodity and policy committees.

Western Mining Council—Attended meetings.

Fairs and Mineral Shows

Amador County Fair
Benicia Gem and Mineral Show
California Federation of Mineralogical Societies, Fresno
California State Fair—Set up mineral commodity and fluorescent exhibit
Castro Valley Gem and Mineral Show
Humboldt Mineral Society Show
Monterey Bay Mineral Society Annual Gem and Mineral Show
Orange Belt Mineralogical Society Gem and Mineral Show, San Bernardino
Sacramento Mineral Show
San Bernardino County Fair
San Francisco Gem and Mineral Society Show
San Joaquin Gem and Mineral Show, Stockton
San Luis Obispo Gem and Mineral Show
San Mateo Mineral Society Show
Santa Clara Valley Gem and Mineral Show
Santa Cruz Gem and Mineral Society Show
Sonoma County Fair

Representatives were in continuous attendance throughout most of the above fairs and shows, exhibiting mineral specimens and publications, identifying minerals, giving information on minerals and mining, and selling publications.

Mineral and Geological Societies

Benicia Gem and Mineral Society
Castro Valley Gem and Mineral Society
Contra Costa Gem and Mineral Society
Contra Costa Hills Club
Crystallographic Society of America
East Bay Mineral Society
Geological Society of Sacramento
LeConte Geological Club
Minerals Association of Northern California
Northern California Geological Society
Palo Alto Geological Society
Peninsula Geological Society
Redwood Gem and Mineral Society
San Mateo Gem and Mineral Society
Sierra Gem and Mineral Society

Standard Oil Rockhounds
Ukiah Rock and Gem Club
Vallejo Mineral Society

Educational

American River Junior College
Association of Geology Teachers, Santa Barbara
Boy Scouts of America—Assisted and advised in set-up of Cub Scout rock show at Scoutorama. Led Cub Scout rock hunt.
California Academy of Sciences
California Institute of Technology
California School of Arts and Crafts
San Francisco State College
Tulare County Teachers Institute
Tule Gem Society, College of Sequoia, Visalia
University of California Clay Committee
University of California Theta Tau Fraternity
University of San Francisco
Western Museums Conference

Business and Industry

Commonwealth Club of San Francisco, Mineral Industries Committee
Inter-County Chamber of Commerce, Redding
Kiwanis Clubs, Menlo Park and Willits
Industrial Promotion Committee, "Forward Redding" conference—Served as mineral consultant.
Lions Club, Placerville
Riverside Board of Trade, Joint meeting with State Mining Board—Panel presentation on mineral resources and industrial development of southern California.
Rotary Club, Santa Cruz
Southern Pacific Land Company
Structural Engineers Association

Miscellaneous

Berkeley Round Table
California Alpine Club of San Francisco
Earthquake Engineering Institute
El Cerrito property owners group
Inter-agency subsidence committee
Methodist men, Montclair
Pacific Oil Scouts and Landmen's Association offshore oil symposium
Spires Club, Oakland
Television program KABC—Appeared with Director of Natural Resources, discussed mineral resources of California and functions of Division of Mines.

Topics of Talks

Earthquakes
Subsidence
Characteristics of active faults
Landslides
Geology and mineral deposits of Bay area
Rocks and minerals of East Bay
Future of mineral industry in California
California mineral resources
Work of Division of Mines
Mineral identification
Geologic occurrence of gems and minerals
New methods of prospecting
Uranium
California jade
Volcanic glasses
Ceramic raw materials
Geologic structure of western San Gabriel Mountains
Geology and occurrence of oil in San Mateo County

Geology of central Sierra Nevada
Sonoma geysers
Mineral deposits in Redding district
Geology and mineral resources of Mendocino County
El Dorado County mineral resources
Active mines and mineral industries in Sacramento area

PUBLICATIONS OF THE DIVISION OF MINES

Public Resources Code:

"2205. The State Mineralogist shall: . . . (h) Issue from time to time such bulletins as he may deem advisable concerning the statistics and technology of the mineral industries of this state."

"2209. The State Mineralogist may fix a price upon and dispose of to the public all publications of the division, including reports, bulletins, maps, registers, or other publications. The price shall approximate the cost of publication and distribution. He may also furnish the publications of the division to public libraries without cost and may exchange publications with geological surveys, scientific societies, and other like bodies."

"2210. All money received by the division from sales of publications issued by the division shall be deposited at least once each month in the State Treasury to the credit of the General Fund. . . ."

Since its establishment in 1880, the California State Mining Bureau, which is now called the Division of Mines, has permanently provided the public with information on mining, geology, and related subjects by means of published documents. These are distributed free to libraries open to the public and exchanged with various scientific institutions; but they are sold at about cost of publication and distribution to private individuals and commercial firms.

The first of the Division's documentary series, the *Report of the State Mineralogist*, started in 1880. This series is now known as the *California Journal of Mines and Geology*. It is a quarterly publication and contains the annual report of the State Mineralogist, but is chiefly devoted to inventories of mines and mineral deposits of the state, treated in county reports. It also includes short papers on various technical topics. Currently the Journal sells for $1.00 per issue, or $3.00 for a 1-year subscription (four issues).

Popularity of certain of the county reports issued in the Journal—such as San Bernardino, Kings, and Inyo Counties—has required their reprinting. Other popular county reports are out of print. About half of 38 county reports in print are more than 10 years old and should be revised.

The series of publications known as the *Bulletin* started in 1888. Generally it has been employed to cover broad subjects, monographs, quadrangle reports, or results of statewide geologic or mineral commodity surveys. The popularity of some of the recent bulletins is indicated by their wide distribution as follows:

Bulletin 170, *Geology of southern California*, a large and expensive series of volumes and maps, priced at $12.00, issued in 5,000 copies, sold out in a few months.

Bulletins 67, 91, 113, 136, and the forthcoming Bulletin 173, *Minerals of California* (first issued in annual reports of 1884, 1887, and as a special report in 1902) has always been so much in demand, selling out periodically, that new revisions have been required. The new volume describes well over 500 species of California minerals.

A complete revision of out-of-print Bulletin 156, *Mineral commodities* *of California,* has now been nearly completed and will be issued as a large volume, the forthcoming Bulletin 176.

Bulletin 141, *Geologic guidebook along Highway 49,* is the Division's best-seller; during this fiscal year it went into its fourth edition of 7,500 copies, having sold 22,500 copies in the first three editions during 6½ years. The only publication that has surpassed this record is the small pamphlet *Legal guide for California prospectors and miners,* which sells for 25¢ and is now in its fifth edition. More than 25,000 copies of this 78-page booklet have been distributed since 1952; before that time it was circulated under the name *Manner of locating and holding mineral claims in California.*

Several bulletins for which there is a constant demand have recently gone out of print. Among these are Bulletin 78, *Quicksilver resources of California,* 1918; Bulletin 118, *Geologic formations and economic development of the oil and gas fields of California,* which has gone through two printings (1943 and 1949); Bulletin 123, *American mining law,* which has gone through four editions, and two printings of the fourth edition (1893, 1923-25, 1931, 1943, and 1948); Bulletin 135, *Placer mining for gold in California,* which has gone through two editions (1946 and 1950); and Bulletin 158, *Evolution of the California landscape,* 1952.

There is a particularly large demand for the reprinting of Bulletins 170, 158, 135, 123, and a revision of 118.

The Division's *Special Report* series was started in 1950. Forty-six special reports have been issued to date, and three are in press; two, Special Report 10A, *Nephrite jade and associated rocks of the Cape San Martin region, Monterey County, California,* and Special Report 37, *Rosamond uranium prospect, Kern County, California,* have been through two editions and are again out of print.

In February 1948, the first issue was distributed of *Mineral Information Service,* "a monthly news release concerning the mineral resources and industry of California, designed to inform the public of the discoveries, operations, markets, statistics, and new publications." From a small original circulation, the magazine has reached a present average distribution of 39,000. This little pamphlet has been issued gratis, published on the offset press from typed pages and accompanied by photographs and drawings. Its contents are varied, but it usually contains an article on some one mineral commodity. In addition it published information of current interest on new mining industries, mineral markets, available new publications, and a list of the latest topographic quadrangles issued by the U. S. Geological Survey in California.

Response from the public from all over the world shows that *Mineral Information Service* is the most generally desired of all the Division's publications. It has served to stimulate interest in the mineral industry and to cause greatly increased sales of all other documents published by the Division.

The following list gives the titles of all publications of the Division of Mines for fiscal 1955-56. It is in two parts—publications issued during fiscal 1955-56, and publications in press at the close of fiscal 1955-56. The affiliation of authors is shown by the letters in parenthesis: (SDM), member of State Division of Mines staff; (U), member of a university faculty or student body; (C), consultant or member of a commercial firm; (GS), U. S. Geological Survey staff member.

PUBLICATIONS IN PRESS AT CLOSE OF FISCAL YEAR 1955-56

Mineral Information Service (SDM)

Vol. 9, No. 7, July 1, 1956: Lead and zinc in California; Announcement of new publications: New list of exploratory holes and revised oil and gas map; Basic studies in the clay industry—new symposium on clay fabrication; Mineral marketing; Mineral news notes.

California Journal of Mines and Geology

Vol. 52, No. 4, October 1956: Mines and mineral resources of El Dorado County, California, by William B. Clark (SDM) and Denton W. Carlson (SDM); National minerals policy (reprint of Governor's conference resolutions); Index to volume 52.

Bulletins

Bulletin 173, Minerals of California, by Joseph Murdoch (U) and Robert W. Webb (U).

Bulletin 174, Pumice, pumicite and volcanic cinders in California, by Charles W. Chesterman (SDM), containing an article entitled Technology of pumice, pumicite, and volcanic cinders, by F. Sommer Schmidt (C).

Bulletin 176, Mineral resources of California (SDM), Lauren A. Wright, ed., containing in part: Molybdenum, by Richard M. Stewart; Tin, by C. H. Gray Jr.; Wollastonite, by Bennie W. Troxel; Strontium minerals, by William E. Ver Planck; Sand and gravel, by Thomas E. Gay Jr.; Platinum and allied metals, by William B. Clark; Salt, by William E. Ver Planck; Natural-gas liquids, by Earl W. Hart; Natural gas, by Earl W. Hart; Magnesium and magnesium compounds, by William E. Ver Planck; Barite, by Charles J. Kundert; Bromine, by William E. Ver Planck; Cadmium, by J. Grant Goodwin; Calcium chloride, by William E. Ver Planck; Copper, by John C. O'Brien; Gypsum, by William E. Ver Planck; Iodine, by William E. Ver Planck; Nitrogen compounds, by William E. Ver Planck; Zinc by J. C. O'Brien; Antimony, by Harold B. Goldman; Carbon dioxide, by Harold B. Goldman; Lithium and lithium compounds, by William E. Ver Planck; Mercury, by Fenelon F. Davis; Sulfur and sulfuric acid, by Philip A. Lydon; Phosphates, by Charles J. Kundert; Petroleum, by Charles W. Jennings.

Note: When completed, this bulletin will contain, in all, about 78 separate reports; only those completed are shown here.

PUBLICATIONS ISSUED DURING FISCAL YEAR 1955-56

Mineral Information Service (SDM)

Vol. 8, No. 7, July 1, 1955: Land subsidence in California; Earthquakes damage at Wilmington; Cinnabar in San Mateo County; New topographic maps; Lead production increased; New geology text.

Vol. 8, No. 8, August 1, 1955: Saline Valley area, Inyo County; Mining claims in national parks and monuments: New topographic maps; New issue of French Bibliographical Digest; F. C. Van Deinse; Journal reprinted; New geologic report; New Journal; Mineral marketing information; George W. Hallock; Notice to subscribers.

Vol. 8, No. 9, September 1, 1955; Geology of southern California—Bulletin 170; Newly published U. S. G. S. topographic maps of California; New cement plant for southern California; New bulletin will be aid to prospectors; Mineral marketing information; New book on Mother Lode.

Vol. 8, No. 10, October 1, 1955: Chromite in California; New mining law; Mining branch holds fall meeting; California gold and silver production increased; Mercury 1955; Mineral marketing information; New geologic maps of area in Los Angeles County.

Vol. 9, No. 11, November 1, 1955: Molybdenum; Newly published U. S. G. S. topographic maps of California; New glass sand operations; New glossary for engineers; From clay to tile; New geologic map sheets.

Vol. 8, No. 12, December 1, 1955: Sand and gravel; New mining law.

Vol. 9, No. 1, January 1, 1956: Mother Lode book reprinted; Current mining activities along Highway 49; New book on Temecula area; L. A. Norman leaves Division; New map exhibit; New topographic maps; Index to volume 8; Price hange (Special Report 23); Gift by W. S. T. Smith; Staff changes; Bibliography n sea.

Vol. 9, No. 2, February 1, 1956: Highlights in California mineral production, 1955; New soils map; New journal; California topographic maps, 1955; New Death Valley book; Stratigraphic geology; Student exhibit.

Vol. 9, No. 3, March 1, 1956: Titanium; Recommendations for a national minerals policy; W. E. Wrather, Director of U. S. G. S. retires; Open file report on Blue Ledge mine; New book on uranium and thorium deposits in California; Mineral marketing information; California topographic maps; New books for collectors and students.

Vol. 9, No. 4, April 1, 1956: Earthquakes and faults in California; New earthquake book; AIME to meet in Seattle; Tungsten program closing; C. J. Kundert leaves Division; Sand and gravel featured in new issue of Journal; California petroleum, 1955.

Vol. 9, No. 5, May 1, 1956: Tungsten; Topographic maps; New sand and gravel plant to use heavy media; Geology of southern California out of print; Map showing California topographic mapping coverage since World War II, June 30, 1955.

Vol. 9, No. 6, June 1, 1956: Gypsum; Dimension stone; Topographic maps; Mineral marketing; Shasta area active; Limestone mine working; Gold mine working.

California Journal of Mines and Geology

Vol. 51, No. 3, July 1955: Manganese deposits on the northwest Pacific sea floor, by Robert S. Dietz (U); Mines, mineral resources, and mineral industries of Marin County, California, by William E. Ver Planck (SDM).

Vol. 51, No. 4, October 1955: California mineral commodities in 1952 and 1953, by Henry H. Symons (SDM) and Fenelon F. Davis (SDM); Mines and mineral resources of San Mateo County, California, by Fenelon F. Davis (SDM); Index to volume 51 (SDM).

Vol. 52, No. 1, January 1956: Annual report of the State Mineralogist for the 106th fiscal year, by Olaf P. Jenkins (SDM); Sand and gravel for concrete aggregate, by Harold B. Goldman (SDM).

Vol. 52, No. 2, April 1956: Basic studies in the clay industry, George B. Cleveland, editor; Clays and clay mineralogy, by Joseph A. Pask (U); Properties of clays, by W. J. Knapp (U); Mineral exploration and winning of clays, by E. H. Wisser (U) and Mort D. Turner (SDM); Clay testing, by W. O. Brandt (C); Testing of clays, by L. H. Lohman (C); Soluble salt deposits on clay wares, by Joseph A. Pask (U); Clay preparation and stiff-mud forming methods, by Clark Sutherland (C); The drying of clay products, by R. K. Hursh (U); The firing process, by R. K. Hursh (U); Temperature measurement in kilns, by James L. Hall (C); Pyrometry, by Ralph I. Brogie (C).

Vol. 52, No. 3, July 1956: Lode gold mines of the Alleghany-Downieville area, Sierra County, California, by Denton W. Carlson (SDM) and William B. Clark (SDM); History of borax production in the United States, by W. E. Ver Planck (SDM).

Bulletins

Bulletin 170, Geology of southern California, ed. by Richard H. Jahns (U). PREFACE, by Richard H. Jahns (U). CHAPT. I, General features: Investigations and problems of southern California geology, by Richard H. Jahns (U); Climate, vegetation, and land use in southern California, by Harry P. Bailey (U); Indian occupation in southern California, by Robert F. Heizer (U). CHAPT. II, Geology of the natural provinces: General geology of the Mojave Desert region, California, by D. F. Hewett (GS); Geology of the Imperial Valley region, California, by T. W. Dibblee, Jr. (GS); Geology of the Peninsular Range province, southern California and Baja California, by Richard H. Jahns (U); Geology of the Oceanside-San Diego coastal area, southern California, by Leo George Hertlein (CAS) and U. S. Grant (U); Geology of the Los Angeles basin, by A. O. Woodford (GS); J. E. Schoellhamer (US), J. G. Vedder (GS), and R. F. Yerkes (GS); Geology of the Transverse Range province, southern California, by Thomas L. Bailey (C) and Richard H. Jahns (U); General geology of the offshore area, southern California, by Kenneth O. Emery (U); Geological summary of the San Joaquin Valley, California, by Harold W. Hoots (C), Ted L. Bear (C), and William D. Kleinpell (C); Geology of the Tehachapi Mountains, California by John P. Buwalda (U); Geology of the central and southern Death Valley region, California, by Levi F. Noble (GS) and Lauren A. Wright (SDM), CHAPT. III, Historical geology; Correlation of sedimentary formations in southern California, by Gordon B. Oakeshott (SDM), Charles W. Jennings (SDM), and Mort D. Turner

(SDM); Rocks of Paleozoic age in southern California, by Charles W. Merriam (GS); Mesozoic formations and faunas, southern California and northern Baja California, by W. P. Popenoe (U); The marine Cenozoic of southern California, by J. Wyatt Durham (U); Fossil foraminifera of the Los Angeles and Ventura regions, California, by M. L. Natland (C) and W. T. Rothwell, Jr. (C); Cenozoic land life of southern California, by Donald E. Savage (U) and Theodore Downs (L. A. County Mus.), with illustrations by Owen J. Poe (U); Marine-nonmarine relationships in the Cenozoic section of California, by J. Wyatt Durham (U), Richard H. Jahns (U), and Donald H. Savage (U); Tertiary basins of southern California, by William H. Corey (C). CHAPT. IV, Structural features: Tectonics of faulting in southern California, by Mason L. Hill (C); A fault map of the Mojave Desert region, by D. F. Hewett (GS); Seismicity of southern California, by Charles F. Richter (U) and Beno Gutenberg (U); Rocks and structure of the northern Providence Mountains, San Bernardino County, California, by John C. Hazzard (C); The San Andreas fault zone from Soledad Pass to Cajon Pass, California, by Levi F. Noble (GS); Strike-slip displacement of the San Gabriel fault, southern California, by John C. Crowell (U); Turtlebacks in the central Black Mountains, Death Valley, California, by H. Donald Curry (C). CHAPT. V, Geomorphology: Some physiographic aspects of southern California, by Robert P. Sharp (U); Geomorphic processes in the desert, by Eliot Blackwelder (U); Physiographic features of faulting in southern California, by Robert P. Sharp (U); Beach and nearshore processes along the southern California coast, by Douglas L. Inman (U); Pleistocene lakes and drainage in the Mojave region, southern California, by Eliot Blackwelder (U); Pleistocene glaciation in the upper San Joaquin Basin, Sierra Nevada, by Joseph H. Birman (U); Marine terraces of the Ventura region and the Santa Monica Mountains, California, by William C. Putnam (U); The nature of Cima Dome, by Robert P. Sharp (U); History of the lower Colorado River and the Imperial depression, by Chester R. Longwell (U). CHAPT. VI, Hydrology: Hydrology of the Los Angeles region, by Harold C. Troxell (GS) and Walter Hofmann (GS); Hydrology of the Mojave Desert, by Harold C. Troxell (GS) and Walter Hofmann (GS); Geology and hydrology of Ventura County, by R. G. Thomas (Cal. Div. Water Res.), E. C. Marliave (Cal. Div. Water Res.), L. B. James (Cal. Div. Water Res.), and R. T. Bean (Cal. Div. Water Res.). CHAPTER VII, Mineralogy and petrology: Minerals in southern California, by Joseph Murdoch (U) and Robert W. Webb (U); Problems of the metamorphic and igneous rocks of the Mojave Desert, by Thane H. McCulloh (U); The batholith of southern California, by Esper S. Larsen, Jr. (U); Miocene volcanism in coastal southern California, by John S. Shelton (U); Pegmatites of southern California, by Richard H. Jahns (U); Contact metamorphism in southern California, by Ian Campbell (U); Contact metamorphism at Crestmore, California, by C. Wayne Burnham (U); Anorthosite complex of the western San Gabriel Mountains, southern California; by Donald V. Higgs (C). CHAPT. VIII, Mineral deposits and mineral industry: Salines in southern California, by William E. Ver Planck (SDM); Deposits of saline minerals in southern California, by Russell W. Mumford (C); The Mountain Pass rare-earth deposits, by Jerry C. Olson (GS) and Lloyd C. Pray (U); Tungsten in southeastern California, by Paul C. Bateman (GS) and William P. Irwin (GS); Base metal and iron deposits of southern California, by Donald Carlisle (C), Dudley L. Davis (C), Malcolm B. Kildale (C), and Richard M. Stewart (SDM); Gold and silver mining districts in the Mo-ave Desert region of southern California, by Dion L. Gardner (C); Occurrence and use of nonmetallic commodities in southern California, by Lauren A. Wright (SDM), Charles W. Chesterman (SDM), and L. A. Norman, Jr. (SDM). CHAPT. X, Oil and gas: History of oil exploration and discovery in California, by Harold V. Hoots (C) and Ted L. Bear (C); Origin, migration, and trapping of oil in south-rn California, by Frank S. Parker (C); Oil and gas production in California, by Frank B. Carter (C); Stratigraphic traps for oil and gas in the San Joaquin Valley, y Harold W. Hoots (C), Ted L. Bear (C), and William D. Kleinpell (C). CHAPT. X, Engineering aspects of geology: Earthquakes and earthquake damage in southern California, by Charles F. Richter (U); Residential building-site problems in Los Angeles, California, by John T. McGill (U); Subsidence of the Wilmington oil field, California, by U. S. Grant (U). GEOLOGIC GUIDE NO. 1, Geologic guide for the western Mojave Desert and Death Valley region, southern California, by Lauren A. Wright (SDM) and Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 2, Geo-ogic guide through the Ventura Basin and adjacent areas, southern California, by Charles W. Jennings (SDM) and Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 3, Geologic guide for the Los Angeles Basin, southern California, by Bennie W. Troxel (SDM). GEOLOGIC GUIDE NO. 4, Geologic guide for the southwestern part of the Los Angeles Basin, southern California, by Orville L. Bandy (U) and Kenneth O. Emery (U). GEOLOGIC GUIDE NO. 5, Geologic guide for the northern part of the Peninsular Range province, southern California, by Richard H. Jahns (U). MAP SHEETS: No. 1, Geology of Cuyama Valley and adjacent ranges, San Luis Obispo, Santa Barbara, Kern, and Ventura Counties, by Irving T. Schwade (C); No. 2, Geology of the Tunis-Pastoria Creek area, Kern County, by Paul B Harris (C); No. 3, Geology of the Sespe Creek-Pine Mountain area, Ventura County, by William R. Merrill (C); No. 4, Geology of the western Ventura Basin Santa Barbara, Ventura, and Los Angeles Counties, by Thomas L. Bailey (C) No. 5, Geology of a part of the eastern Ventura Basin, Los Angeles County, by Edward L. Winterer (GS) and David L. Durham (GS); No. 6, Geology of the Soledad Basin, Los Angeles County, by Richard H. Jahns (U) and William R. Muehlberger (U); No. 7, Geology of the Ridge Basin area, Los Angeles and Ventura Counties by John C. Crowell (U); No. 8, Geology of the Santa Monica Mountains, Los Angeles and Ventura Counties, by Cordell Durrell (U); No. 9, Geology of the western San Gabriel Mountains, by Gordon B. Oakeshott (SDM); No. 10, Geology of the Little Tujunga area, Los Angeles County, by Benjamin F. Howell, Jr. (U); No. 11 Geologic map of the Owens Valley region, California, by Paul C. Bateman (GS) and C. W. Merriam (GS); No. 12, Geology of the Talc City area, Inyo County, by Thomas E. Gay, Jr. (SDM) and Lauren A. Wright (SDM); No. 13, Geology of the Redrock Canyon-Last Chance Canyon area, Kern County, by T. W. Dibblee, Jr (GS); No. 14, Geology of the Rosamond Hills, Kern County, by James A. Nobl (U); No. 15, Geology of a part of the Shadow Mountains, western San Bernardino County, by Bennie W. Troxel (SDM); No. 16, Geology of the Quail Mountains San Bernardino County, by William R. Muehlberger (U); No. 17, Geology of the Alexander Hills area, Inyo and San Bernardino Counties, Lauren A. Wrigh (SDM); No. 18, Geology of the Barstow area, San Bernardino County, by Olive E. Bowen, Jr. (SDM); No. 19, Geology of the Silurian Hills, San Bernardino County, by Donald H. Kupfer (U); No. 20, Geology of the north side of San Gorgonio Pass, Riverside County, by Clarence R. Allen (U); No. 21, Geology of the Corona-Elsinore-Murrieta area, Riverside County, by Cliffton H. Gray, Jr. (SDM) No. 22, A typical portion of the southern California batholith, San Diego County by Richard Merriam (U); No. 23, Geology of the Jacumba area, San Diego and Imperial Counties, by Baylor Brooks (U) and Ellis Roberts (U); No. 24, Geolog of a portion of Joshua Tree National Monument, Riverside County, by John J. W Rogers (U); No. 25, Geology of the Carpinteria district, Santa Barbara County, b Harold M. Lian (C); No. 26, Geology of the Rincon oil field, Ventura County, b Robert H. Paschall (C); No. 27, Geology of the San Miguelito oil field, Ventur County, by Richard B. Haines (C) and Francis E. Minshall (C); No. 28, Geolog and occurrences of oil in the Ojai-Santa Paula area, Ventura County, by Spencer F Fine (C); No. 29, Geology of the South Mountain oil field, Ventura County, b R. R. Baddley (C); No. 30, Geology of the Honor Rancho oil field, Los Angele County, by Donald G. Herring, Jr. (C); No. 31, Geology of the Placerita oil field Los Angeles County, by Gordon B. Oakeshott (SDM); No. 32, Geology of th Dominguez oil field, Los Angeles County, by Doyle T. Graves (C); No. 33, Geolog of the Wilmington oil field, by Read Winterburn (C); No. 34, Geology of the Lon Beach oil field, Los Angeles County, by Paul H. Dudley (C).

Bulletin 171, Earthquakes in Kern County, California during 1952, Gordon B Oakeshott, ed. (SDM). PART I, Geology: The Kern County earthquakes in Cal fornia's geologic history, by Gordon B. Oakeshott (SDM); Geology of the southeastern margin of the San Joaquin Valley, by T. W. Dibblee, Jr. (GS); Ker Canyon lineament, by Robert W. Webb (U); Nature of movements on active fault in southern California, by Mason L. Hill (C)j; Geological effects of the Arvi Tehachapi earthquakes, by John P. Buwalda (U) and Pierre St. Amand (U) Ground fracture patterns in the southern San Joaquin Valley resulting from th Arvin-Tehachapi earthquake, by Archer H. Warne (C); Arvin-Tehachapi earthquak damage along the Southern Pacific Railroad near Bealville, California, by Donal H. Kupfer (GS), Siegfried Muessig (GS), George I. Smith (GS), and George N White (GS); Measurements of earth movements in California, by C. A. Whitte (U. S. Coast & Geodetic Survey); Effect of Arvin-Tehachapi earthquake on sprin and stream flow, by Revoe C. Briggs (GS) and Harold C. Troxell (GS); Wate level fluctuation in wells, by G. H. Davis (GS), G. F. Worts, Jr. (GS), an H. D. Wilson, Jr. (GS); Seismic prospecting for petroleum and natural gas i the Great Valley of California, by Joshua L. Soske (C); Application of seism methods to petroleum exploration in the San Joaquin Valley, by Maurice Sklar (C PART II, Seismology: General introduction to seismology, by H. Benioff (U) an

B. Gutenberg (U); The major earthquakes of California: a historical summary, by V. L. VanderHoof (C); Seismic history of the San Joaquin Valley, by C. F. Richter (U); Seismograph development in California, by Hugo Benioff (U); Seismograph stations in California, by B. Gutenberg (U); epicenter and origin time of the main shock on July 21 and travel times of the major phases, by B. Gutenberg (U); The first movement in longitudinal and transverse waves of the main shock and the direction of slip, by B. Gutenberg (U); Magnitude determination for larger Kern County shocks, 1952, effects of station azimuth and calculation methods, by B. Gutenberg (U); Foreshocks and aftershocks, by C. F. Richter (U); Mechanism and strain characteristics of the White Wolf fault as indicated by the aftershock sequence, by Hugo Benioff (U); Relation of the White Wolf fault to the regional tectonic pattern, by Hugo Benioff (U); Strong-motion records of the Kern County earthquakes of July 21, 1952, by Frank Neumann (U. S. Coast & Geodetic Survey) and William K. Cloud (U. S. Coast and Geodetic Survey). PART III, Structural damage: Arvin-Tehachapi earthquake—structural damage as related to geology, by G. Schlocker (GS) and Dorothy H. Radbruch (GS); Earthquake damage to oil fields and to the Paloma Cycling Plant in the San Joaquin Valley, by Robert L. Johnston (C); Highway damage resulting from the Kern County earthquakes, by O. W. Perry (Calif. Div. Highways); Damage to waterworks systems, Arvin-Tehachapi earthquake, by H. G. Hemberg (L. A. Dept. Water & Power); Damage to electrical equipment caused by Arvin-Tehachapi earthquake, by G. A. Peers (PG&E Co.); Earthquake damage to railroads in Tehachapi Pass (SPRR); Earthquake damage to elevated water tanks, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald F. Moran (Pacific Fire Bur.); Earthquake damage to California crops, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald F. Moran (Pacific Fire Rating Bur.); Structural damage to buildings, by Karl V. Steinbrugge (Pacific Fire Rating Bur.) and Donald F. Moran (Pacific Fire Rating Bur.); The design of structures to resist earthquakes by G. W. Housner (U).

Special Reports

Special Report 40, Geology of the Calaveritas quadrangle, Calaveras County, California by Lorin D. Clark (GS).

Special Report 41, Geology of the Angels Camp and Sonora quadrangles, Calaveras and Tuolumne Counties, California, by John H. Eric (GS), Arvid A. Stromquist (GS), and C. Melvin Swinney (GS).

Special Report 43, Geology of a portion of the Elsinore fault zone, California, by John F. Mann, Jr. (U).

Special Report 44, Bibliography of marine geology and oceanography, California coast, by Richard Terry (U).

Reprints

Journal, vol. 50, nos. 3 and 4, July-October 1954: Mines and mineral resources of Los Angeles County, California, by Thomas E. Gay, Jr. (SDM) and Samuel R. Hoffman (SDM); The Cool-Cave Valley limestone deposits, El Dorado and Placer Counties, California, by William B. Clark (SDM); Annual report of the State Mineralogist, Chief of the Division of Mines, for the 105th fiscal year, July 1, 1953 to June 30, 1954, by Olaf P. Jenkins (SDM); Index to volume 50 (SDM).

Bulletin 141, Geologic guidebook along Highway 49—Sierran gold belt: Sierran roads of today and yesterday, by Dorothy G. Jenkins (C); The discovery of gold in California, by Donald C. Cutter (U); History of placer mining for gold in California, by Charles V. Averill (SDM); Sierra Nevada province, by Olaf P. Jenkins (SDM); Geologic history of the Sierran gold belt, by Olaf P. Jenkins (SDM); History of mining and milling methods in California, by C. A. Logan (SDM); Geologic maps and notes along Highway 49, by Oliver E. Bowen, Jr. (SDM) and Richard A. Crippen, Jr. (SDM); The formation of quartz veins, by John A. Burgess (C); Mining on Carson Hill, by John A. Burgess (C); Survey of building structures of the Sierran gold belt, 1848-70, by Robert F. Heizer (U) and Franklin Fenenga (U).

Bulletin 165, Geology and mineral deposits of Barstow quadrangle, San Bernardino County, California, by Oliver E. Bowen, Jr. (SDM); Thermal properties of ceramic materials from Barstow quadrangle, California, by Joseph A. Pask (U) and Oliver E. Bowen, Jr. (SDM).

Publications of the California State Division of Mines to July 1, 1955 (SDM).

Legal guide for California prospectors and miners, compiled under the direction of L. A. Norman, Jr. (SDM).

Map showing mines and mineral deposits of Inyo County, California (SDM).

County reports.

County	Journal	Status (available unless noted O.P. (out of print))
Alameda	April 1950	O.P. New report assigned and in progress.
Alpine	October 1931	
Amador	January 1954	
Butte	July 1949	
Calaveras	July 1936	O.P. New report assigned and in progress.
Colusa	July 1929	
Contra Costa	October 1951	O.P. New report assigned and in progress.
Del Norte	October 1952	
El Dorado	July 1938	O.P. New report completed for early publication.
Fresno	July 1951	
Glenn	January 1952	O.P. No assignment made.
Humboldt	October 1941	
Imperial	April 1942	O.P. New report assigned but inactive.
Inyo	January 1951	
Kern	April 1949	O.P. New report assigned and in progress.
Kings	July 1953	
Lake	January 1947	
Lassen	October 1936	
Los Angeles	July-October 1954	
Madera	October 1950	
Marin	July 1955	
Mariposa	April 1928	O.P. New report completed for early publication.
Mendocino	October 1953	
Merced	July 1952	
Modoc	October 1936	
Mono	April 1940	
Monterey	January 1925	O.P. New report assigned and in progress.
Napa	April 1948	
Nevada	July 1941	
Orange	January 1925	O.P. New report assigned and in progress.
Placer	July 1927	O.P. No assignment made.
Plumas	April 1937	
Riverside	July 1945	O.P. No assignment made.
Sacramento	April 1955	
San Benito	January 1947	
San Bernardino	January-April 1953	
San Diego	January 1939	O.P. New report assigned and in progress.
San Francisco	April 1929	O.P. No assignment made.
San Joaquin	January 1955	
San Luis Obispo	October 1935	O.P. No assignment made.
San Mateo	October 1955	
Santa Barbara	October 1925	O.P. No assignment made.
Santa Clara	April 1954	
Santa Cruz	January 1943	
Shasta	April 1939	Available but new report practically complete.
Sierra	January 1942	
Siskiyou	October 1947	
Solano	April 1927	
Sonoma	January 1950	
Stanislaus	April 1947	
Sutter	1920	O.P. No assignment made.
Tehama	July 1946	
Trinity	January 1941	O.P. New report assigned and in progress.
Tulare	October 1930	O.P. New report assigned and in progress.
Tuolumne	January 1949	
Ventura	July-October 1932	O.P. No assignment made.
Yolo	July 1950	
Yuba	April 1952	

INVENTORIES OF MINING ACTIVITIES

Public Resources Code:

"2208. The State Mineralogist or a qualified assistant may at any time enter or examine any and all mines, quarries, wells, mills, reduction works, refining works, and other mineral properties or working plants in this State in order to gather data to comply with the provisions of this chapter."

Surveys of mining activities throughout the state constitute an extremely important aspect of the work of the Division of Mines. The results of the surveys are published as county reports, which consist of complete inventories of the mineral resources of a given county. They summarize all pertinent information on a county's mineral resources, and include current ownership of mineral deposits, nature of the deposits, history of the mining operations, and the current status. They are well illustrated with photographs, charts, and mine maps; more recently they have included a geologic as well as a mineral map of the entire county. The county report is one of the most frequently requested types of publication which the Division distributes.

County reports are published in the quarterly *California Journal of Mines and Geology*. Short reviews and news items concerning mining activities are also published in *Mineral Information Service*. More detailed studies are published in *Special Reports* and *Bulletins*.

During the fiscal year 1955-56, reports on Marin and San Mateo Counties were published, and reports on El Dorado and Mariposa Counties were completed for early publication. A report on Shasta County was very nearly complete and assignments were made and work was under way for reports on Alameda, Calaveras, Contra Costa, Imperial, Kern, Monterey, Orange, San Diego, Trinity, and Tulare Counties.

A special study of the mines and mineral resources of the Saline Valley area, Inyo County, was made at the request of the State Mining Board and the results were published in *Mineral Information Service*. Other mining activities reports that appeared in *Mineral Information Service* during 1955-56 include *Current mining activities along Highway 49*, items on sand and gravel operations, and a brief summary of recent activity in the Shasta copper-mining area.

STATE GEOLOGIC MAP, 1:250,000

Progress has continued on the revision of the state geologic map since the popular 1938 edition (scale 1:500,000) went out of print 5 years ago. The new edition is being compiled on a scale of 1 inch equals 4 miles (1:250,000) which is twice the scale of the previous edition. Each sheet covers an area two degrees east-west by one degree north-south, and 30 sheets will be required to cover the state. Eight sheets, covering part of southern California, have already been published in a preliminary, uncolored edition and are available for $1.00 each. These sheets have been received enthusiastically by both the technical and lay public and many suggestions and new data have been received since their publication, which will be incorporated in a forthcoming colored geologic atlas. Nine additional sheets have been compiled and are ready for drafting, and work is progressing in compilation of geologic data for six more sheets. Recent acquisition of reconnaissance geological maps from the U. S. Geological Survey has provided information on large unmapped areas in the northwestern part of the state and in the Mojave Desert area.

A generalized geologic map of the state on a much smaller scale (1:2,000,000) is being prepared as a supplement to our forthcoming Bulletin 176, which covers all mineral commodities of California. This small map is to accompany a mineral commodity location map which is intended to show the relationship between rock types and mineralization. This will also in general supply the need in schools for a small colored geologic map of the state.

Geologic data for the state geologic map have been generously contributed by many state and federal agencies, universities, oil and mining companies, and hundreds of individuals. It is the intention of the Division of Mines always to keep account of the progress in geologic mapping in the state and to assemble the references and data in a coordinated and usable form.

The final edition of this state geologic map will be printed in many different colors to show the various rock formations. It is very much desired by scientists, engineers, travelers, agriculturists, industrialists, and, in fact, by people in all walks of life. As a basis for study of

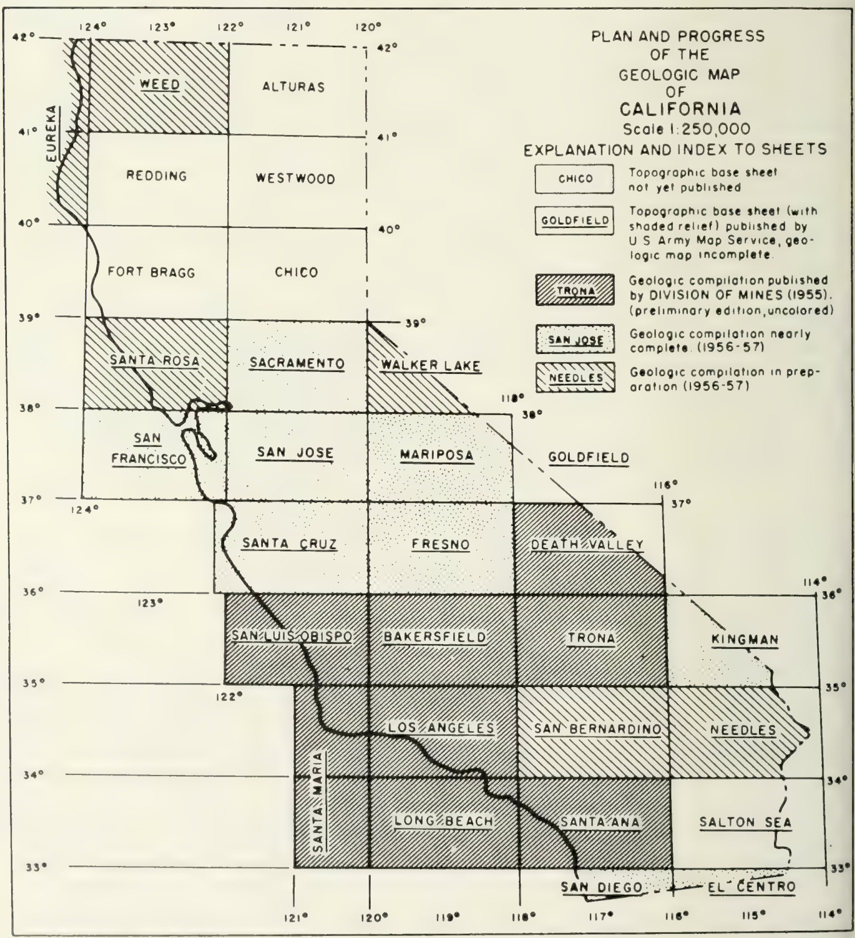
PLAN AND PROGRESS
OF THE
GEOLOGIC MAP
OF
CALIFORNIA
Scale 1:250,000
EXPLANATION AND INDEX TO SHEETS
CHICO
Topographic base sheet not yet published
GOLDFIELD
Topographic base sheet (with shaded relief) published by U S Army Map Service, geologic map incomplete.
TRONA
Geologic compilation published by DIVISION OF MINES (1955). (preliminary edition, uncolored)
SAN JOSE
Geologic compilation nearly complete. (1956-57)
NEEDLES
Geologic compilation in preparation (1956-57)
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
EUREKA
WEED
ALTURAS
REDDING
WESTWOOD
FORT BRAGG
CHICO
SANTA ROSA
SACRAMENTO
WALKER LAKE
SAN FRANCISCO
SAN JOSE
MARIPOSA
GOLDFIELD
SANTA CRUZ
FRESNO
DEATH VALLEY
SAN LUIS OBISPO
BAKERSFIELD
TRONA
KINGMAN
LOS ANGELES
SAN BERNARDINO
NEEDLES
SANTA MARIA
LONG BEACH
SANTA ANA
SALTON SEA
SAN DIEGO
EL CENTRO

Figure 2. Index map of California showing progress of the new geologic map of California, scale 1:250,000.

mineral deposits it is invaluable. The oil industry, departments of water resources, exploration companies, highway planners, and those interested in new industrial plant locations are among those particularly desirous of obtaining this state map.

GEOLOGIC QUADRANGLE PROGRAM

The geologic mapping of quadrangles is done in part by staff members of the Division, in part by professors and graduate students affiliated with universities, in part by private research geologists or geologists who may be affiliated with geological departments of exploration companies, and in part by the U. S. Geological Survey through a cooperative program with the Division of Mines.

Quadrangle mapping projects actively under way by the Division staff include the San Fernando 15-minute quadrangle (geologic map published, report in preparation) by Gordon B. Oakeshott; Matterhorn Peak 15-minute quadrangle (field mapping completed, report in preparation) by Charles W. Chesterman; Shoshone 15-minute and south half of Tecopa 15-minute quadrangles (field mapping in progress) by Lauren A. Wright; Hernandez Valley 15-minute quadrangle (nearly completed) by Charles W. Jennings; Monterey and El Portal 15-minute quadrangles (field work beginning) by Oliver E. Bowen, Jr.; Corona South 7½-minute quadrangle (field mapping completed) by Clifton H. Gray, Jr.; and Shadow Mountains 7½-minute quadrangle (field mapping in progress) by Bennie W. Troxel.

San Fernando quadrangle, in the western San Gabriel Mountains of Los Angeles County, has produced over $50,000,000 worth of petroleum, limestone, graphite, titanium ore, rock, sand, gravel, and volcanic ash. Matterhorn Peak quadrangle, in the high Sierra Nevada, is noted for its historic gold mines and tungsten potential. Shoshone-Tecopa quadrangles, in the southern Death Valley region, have deposits of lead, zinc, silver, gold, talc, saline minerals, pumice and perlite. Hernandez Valley quadrangle, in San Benito and Monterey Counties, has produced lignite, bentonite, gypsum, magnesite, and petroleum. Monterey quadrangle, on Monterey Bay, has yielded sand, diatomite, and dimension stone and is being explored for petroleum. El Portal quadrangle, west of Yosemite Valley, has produced barite, gold, silver, lead, zinc, limestone, dolomite, and slate. Corona South quadrangle is important for clay and sand. The Shadow Mountains quadrangle, in the Mojave Desert, is of greatest interest for the occurrence and mining of tungsten.

The following list shows progress of the basic geologic mapping program to July 1, 1956. ONLY THOSE QUADRANGLES WHICH THE STATE DIVISION OF MINES HAS PUBLISHED OR MAY PUBLISH ARE LISTED. The quadrangles listed are 15-minute (scale 1:62,500), unless otherwise indicated. The letter preceding the name of the quadrangle indicates the affiliation of the geologists who are doing the work:

D—Division of Mines
U—University geologist
S—Federal Geological Survey
(cooperative program)
O—Other professional geologist

The symbol (example, H 15) following the quadrangle name serves as a means of locating it on the accompanying index map.

Recently published geologic map and report:

(S) Angels Camp 7½-min. (P 16)
(U) Antioch (K 16)
(D) Barstow 30-min. (C' 29, C' 30, D' 29, D' 30)
(U) Blue Lake (C 5)
(O) Breckenridge Mt. (X 27)
(S) Calaveritas 7½-min. (P 16)
(U) Carquinez (J 16)
(S) Cuyamaca Peak (F' 37)
(U) Ferndale (A 16)
(U) Fortuna (B 6)
(O) Gaviota (R 31)
(U) Healdsburg (G 14)
(U) Jamesburg (L 23)
(U) Lebec 7½-min. (W 29)
(O) Lompoc (Q 30)
(O) Los Olivos (R 30)
(U) Lower Lake (H 13)
(U) Macdoel 30-min. (I 1, I 2, J 1, J 2)
(U) Mare Island (I 16)
(U) Mount Vaca (J 15)
(S) Neenach (X 29)
(U) Ortigalita Peak (O 21)
(U) Petaluma (H 16)
(O) Point Arguello (P 30)
(O) Point Conception (Q 31)
(U) Point Reyes (G 16)
(U) Quien Sabe (N 21)
(O) Saltdale (A' 27)
(U) San Benito (N 22)
(U) San Jose (E½)—Mt. Hamilton (W½) (KL 19)
(U) San Juan Bautista (L 21)
(U) Santa Rosa (H 15)
(U) Sebastopol (G 15)
(U) Sonoma (I 15)
(S) Sonora 7½-min. (Q 17)
(U) Tesla (L 18)
(U) Vacaville (K 15)

Geologic map published, report in preparation:

(U) Copperopolis (P 17)
(U) Hollister (M 21)
(O) Lake Elsinore (C' 34)
(D) San Fernando (Y 31)

Geologic map and report ready for press:

(S) Big Pine (Y 20)
(S) Casa Diablo Mt. (X 18)
(S) Mt. Tom (X 19)
(S) Bishop (Y 19)
(S) Mt. Goddard (X 20)

Geologic map and report nearly ready for press:

(U) Annette 7½-min. (R 27)
(U) Big Bend SW½ (K 4)
(U) Campo (G' 38)
(U) Carbona (M 18)
(U) Colfax S½ (O 12)
(U) Cuyapaipe (G' 37)
(U) Dardanelles Cone (S 15)
(U) Desert Creek Peak (U 14)
(U) Helena (F 5)
(U) Morgan Valley N½ (I 13)
(U) Orestimba (N 19)
(U) Oroville (L 10)
(U) Pleasanton (K 18)

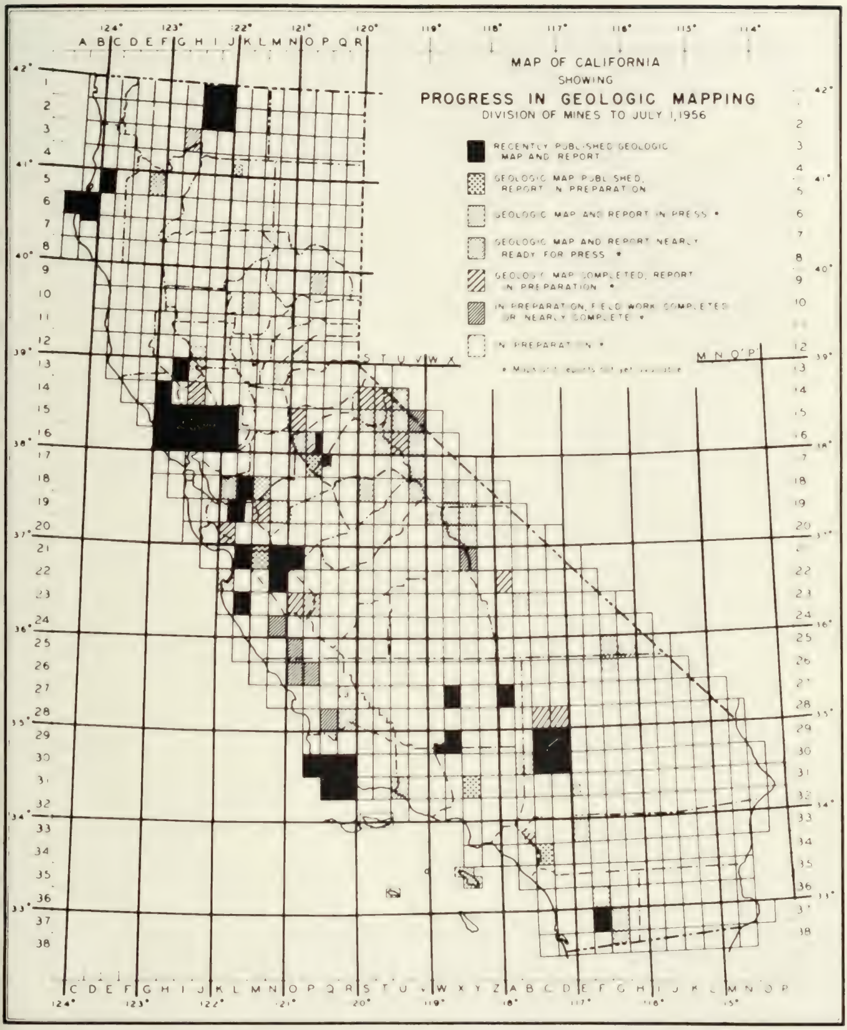
MAP OF CALIFORNIA
SHOWING
PROGRESS IN GEOLOGIC MAPPING
DIVISION OF MINES TO JULY 1, 1956
RECENTLY PUBLISHED GEOLOGIC MAP AND REPORT
GEOLOGIC MAP PUBLISHED, REPORT IN PREPARATION
GEOLOGIC MAP AND REPORT IN PRESS *
GEOLOGIC MAP AND REPORT NEARLY READY FOR PRESS *
GEOLOGIC MAP COMPLETED, REPORT IN PREPARATION *
IN PREPARATION, FIELD WORK COMPLETED OR NEARLY COMPLETE *
IN PREPARATION *
* Maps and reports not yet available
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°

FIGURE 3. Index map of California, showing progress in detailed geologic mapping on topographic quadrangles.

(S) San Andreas, NW$\frac{1}{4}$ (O 16)
(U) Santa Ysabel (F' 36)
(U) Sonora Pass (T 15)
(U) Bodie S$\frac{1}{2}$ (V 16)
(U) Wilbur Springs S$\frac{1}{2}$ (I 12)
(U) Wheeler Peak (U 15)

Geologic map completed, report in preparation:

(D) Corona South 7$\frac{1}{2}$-min. (B' 33)
(S) Darwin (B' 23)
(U) Ebbetts Pass (S 14)
(O) Fremont Peak (C' 28)
(O & D) Hernandez Valley (O 23)
(D) Matterhorn Peak (U 16)
(U) Mount Boardman (M 19)
(S) New Almaden (K 20)
(S) New York Butte (A' 22)

(O) Opal Mt. (D' 28)
(U) St. Helena (I 14)
(S) San Andreas (P 16)
(S) Santa Catalina Island (X 35, Y 35)
(U) Sutter Creek (O 15)
(U) Topaz Lake (T 14)

In preparation, field work completed or nearly complete:

(U) Adelaida (O 26)
(D) Bodie (V 16)
(U) Bradley (O 25)
(U) King City (N 24)
(D) Masonic Mt. (V 15)
(S) Mount Pinchot (Y 21)
(U) Nipomo (Q 28)
(U) Paso Robles (26)

In preparation:

(O) Auburn (N 13)
(D) Avawatz Pass N½ (G' 26)
(D) Bodie (V 16)
(U) Blairsden (P 9)
(U) Branch Mt. (R 28)
(U) China Mt. S½ (H 3)
(S) Devils Postpile (V 18)
(D) El Portal (S 18)
(U) Lucerne Valley SW¼ (E' 31)
(S) Mono Craters (V 17)
(D) Monterey (K 22)
(D) Mt. Abbot S½ (W 19)
(O) New Idria (P 23)
(U & D) Shadow Mts. 7½-min. (B' 30)
(D) Shoshone (G' 25)
(D) Tecopa S½ (H' 25)
(U) Valley Springs (O 16)

NORTH COAST GEOLOGIC GUIDEBOOK

In 1952 the Division inaugurated a program of reconnaissance geologic mapping in previously unmapped areas of the Klamath Mountains. This is a region of rich mineral potential, about which there is very little basic geologic information. Geologic mapping of five quadrangles—the Eureka, Trinidad, Orick, Klamath, and Crescent—along the coast has been completed. On the basis of this mapping, a geologic guidebook to the coastal area between Eureka and the Oregon border is being prepared. It is the intention of the Division to continue the geologic guidebook work along the entire coast of California. It is a region of interest to the public, especially since many sections now are State Parks, where maps and descriptions of the rocks are always much needed.

BACKLOG OF COMPLETED UNPUBLISHED REPORTS

Besides the long list of quadrangle geologic maps and reports in progress, and projects underway by Division of Mines geologists, there are many contributions in the files of the Division waiting processing for publication. Titles of completed unpublished reports, ready for publication, when funds are available, are listed as follows:

Bishop, W. C., Geology of a part of the Santa Susana Mountains, California
Carman, M. F., Jr., Geology of the Lockwood Valley area, California
Chandra, D. K., Geology of the Colfax and Forest Hill quadrangles, California
Dibblee, T. W., Jr., Geology of Caliente quadrangle, California
Hall, C. A., Brooks, S. A., and Jones, D. L., Geology of the Pescadero-Año Nuevo area, California

Herrera, L. J., Jr., Geology of the Tent Hills quadrangle, California
Marsh, O. T., Geology of the Orchard Peak area, California
McLaughlin, D. H., Geology of the Wartham Canyon area, California
Merriam, R., Geology of the Campo and Cuyapaipe quadrangles, California
Norris, R. M., Geology of San Nicolas Island, California
Pease, M. H., Jr., Geology of the Sobrante anticline, California
Pelletier, W. J., Geology of the Carbona quadrangle, California
Peryam, R. C., Geology of the Annette quadrangle, California
Richards, A. F., Geology of Santa Barbara Island, California
Richmond, J. F., Petrology and structure of the San Bernardino Mountains north of Big Bear Lake, California
Rogers, J. J. W., Geology of Joshua Tree National Monument, California
Sanborn, A. F., Geology and paleontology of the Big Bend quadrangle, California
Shuler, E. H., Geology of the San Timoteo badlands, California
Steuer, N. B., Tungsten deposits of the Mud Lakes district, Fresno County, California

LIBRARY

Public Resources Code:

> "2205. The State Mineralogist shall: . . .
>
> (d) Provide a library of books, reports, and drawings bearing upon the mineral industries, the sciences of mineralogy and geology, and the arts of mining and metallurgy, such library constituting the library of the division.
>
> (e) Make a collection of models, drawings, and descriptions of the mechanical appliances used in mining and metallurgical processes.
>
> (f) Preserve and so maintain such collections and library as to make them available for reference and examination, and open to public inspection at reasonable hours.
>
> (g) Maintain, in effect, a bureau of information concerning the mineral industry of this State to consist of such collections and library, and arrange, classify, catalogue, and index the data therein contained, in a manner to make the information available to those desiring it."

The Division of Mines Library, with a technical and professional collection of over 20,000 books and serial volumes, is the starting point for much of the research activity of the staff and, along with the mineral exhibits and laboratory, its resources are basic to the public information service of the Division. It is a complete depository for the publications of the U. S. Bureau of Mines and the U. S. Geological Survey, including unpublished geologic reports on California areas and mineral deposits

Figure 4. Library reference room, south end of Ferry Building. *Photo by Mary Hill.*

placed on open file. There are extensive files of publications of the geological surveys and mining bureaus of the various states, of other countries, and of the leading American, Canadian, and British mining and geological societies. For historical studies, there are the reports and atlases of the early explorations and railroad surveys of the West, and books and pictorial material on the gold rush and early California mining.

In a textbook or government report, scholarly journal or hobbyist magazine, the reader may find the reference he needs on a wide range of subjects from the economics of the petroleum industry to the cutting and polishing of stones. With the development of broader public interest in minerals and mineral industries has come greater recognition of the information services available and the value of looking up the references which may be of help in solving a technical mining problem or in going ahead with a mining venture.

A substantial increase in the major activity of the Library, service to readers, is shown by the records for use of materials by the staff and visitors. Although there was a relatively small increase in the number of visitors, a total of nearly 17,000 items were used in the Library.

During the year there has been increased use of the Library's materials by other libraries and organizations through interlibrary loans. Seventy-six loans were made. Requests from defense installations in the Bay area accounted for most of the increase in this activity.

The publications of the Division of Mines are distributed without charge to California libraries and schools, and a number of the larger public libraries and university libraries throughout the country are also depositories with extensive files available for reference, to which inquirers in many areas may be directed. Much of the Library correspondence is concerned with this program. Visits to schools and libraries by the librarian to discuss the use of these materials in the study of California resources were continued during the year, although on a somewhat reduced schedule. Absences from the office were restricted because of changes in the library staff.

New exchanges were established with 16 institutions abroad, the latest Shizuoka University, Japan. In the Library's holdings of international geological and mining materials are the publications of countries of the Pacific region—Australia, New Zealand, and Japan. Materials from seven Japanese institutions, including nearly all of the impressive postwar output of geologic reports and maps of the Geological Survey of Japan, are on file.

A set of plastic relief maps of California and adjoining areas of Nevada on the scale of approximately 4 miles to the inch were obtained from the Army Map Service. Six of the maps, covering the central portion of the state from Santa Cruz to south of San Luis Obispo on the coast, and to Death Valley and Searles Lake and part of Nevada on the east, have been joined and mounted in the Library. Extension of the display to include the northern and southern California areas is in preparation. The same base from which these plastic relief maps are made is being used by the Division in compilation of the new State Geologic Map.

During the year, there were two donations to the Library of outstanding value and importance. From Dr. W. S. T. Smith, of Menlo Park, came a nearly complete set of the Bulletins, Memoirs, Special Papers, and other publications of the Geological Society of America and a large number of Geologic Folio Atlases, Bulletins, and other publications of the U. S. Geological Survey. Mr. Wilbur H. Grant, consulting geologist and mining engineer of San Francisco, deposited with the Division of Mines an extensive file of his papers and mine reports.

Service:	*1954-55*	*1955-56*
Books, periodicals, and maps used by visitors	9,413	10,679
Books, periodicals, and maps used by staff members	4,964	6,296
Foreign exchange list additions	11	16
Library mailing list additions	97	53
Publications issued by stock order	1,398	858
School kits distributed	155	88
Film loans	15	9
Interlibrary loans	41	86
Conservation education: Visits to libraries and schools	74	30
Receipts:		
Books (By purchase, exchange and donation)	452	510
Total number of classified books at end of fiscal year	10,078	10,388
Periodicals (San Francisco library and branch office subscriptions; exchange subscriptions incl. newspapers)	319	315
Maps and charts	526	466

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TOPOGRAPHIC QUADRANGLE MAP FILE

The Division of Mines receives 16 copies of each newly completed U.S. Geological Survey California topographic quadrangle map that is published. The State Division of Water Resources provides the Division with 10 copies, while an additional 6 are sent direct from the U.S. Geological Survey. The Division also receives from the Survey one copy of each new quadrangle map covering different areas in the western states. A copy of each topographic quadrangle map is mounted on cloth and placed in the Library file for public inspection; other copies are distributed among the three branch offices and the remaining copies filed in reserve stock for field use by staff members. Advance prints of California topographic quadrangles (subject to correction) are received from the U.S. Geological Survey for our inspection and comment before the final map is printed. During the 1955-56 fiscal year the Division received a total of 1,885 finished topographic quadrangles and 385 advance sheets covering different parts of California. During the same period, 865 out-of-state quadrangle maps were received, making a total of 3,135 new quadrangle maps received.

Miscellaneous geologic maps and charts, largely published by the U.S. Geological Survey, are regularly received and added to the Division's Library collection. These include: geologic maps covering quadrangle areas, areas of oil and gas investigations, coal investigations, mineral investigations, geophysical investigations, and state maps indexed to show all areas covered by various maps. During the last fiscal year the Division received and filed approximately 200 maps of this category.

Topographic maps form the basis for all geologic and mineral studies. They are invaluable to the staff of the Division as well as to the interested public. The fine support the Division receives from both the U.S. Geological Survey and the State Department of Water Resources is much appreciated. In each issue of *Mineral Information Service*, the new topographic quadrangle maps made available are announced. This service rendered by the Division of Mines has greatly widened the scope of the public's knowledge and use of these fine basic maps.

MINERAL LABORATORY

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a laboratory in San Francisco for the purposes provided in this chapter."

The Division of Mines maintains a laboratory principally for two well-established purposes: (1) to identify specimens submitted by the public; and (2) to provide laboratory facilities to staff members of the Division who require careful identification of rocks and minerals collected during field investigations.

Testing of the properties of materials for use in manufacturing industries has yet only been partly developed in the Laboratory. This type of work deserves greater attention, since nonmetallic minerals in California have recently shown very extensive economic development. For example, detailed testing of certain materials suitable for ceramic

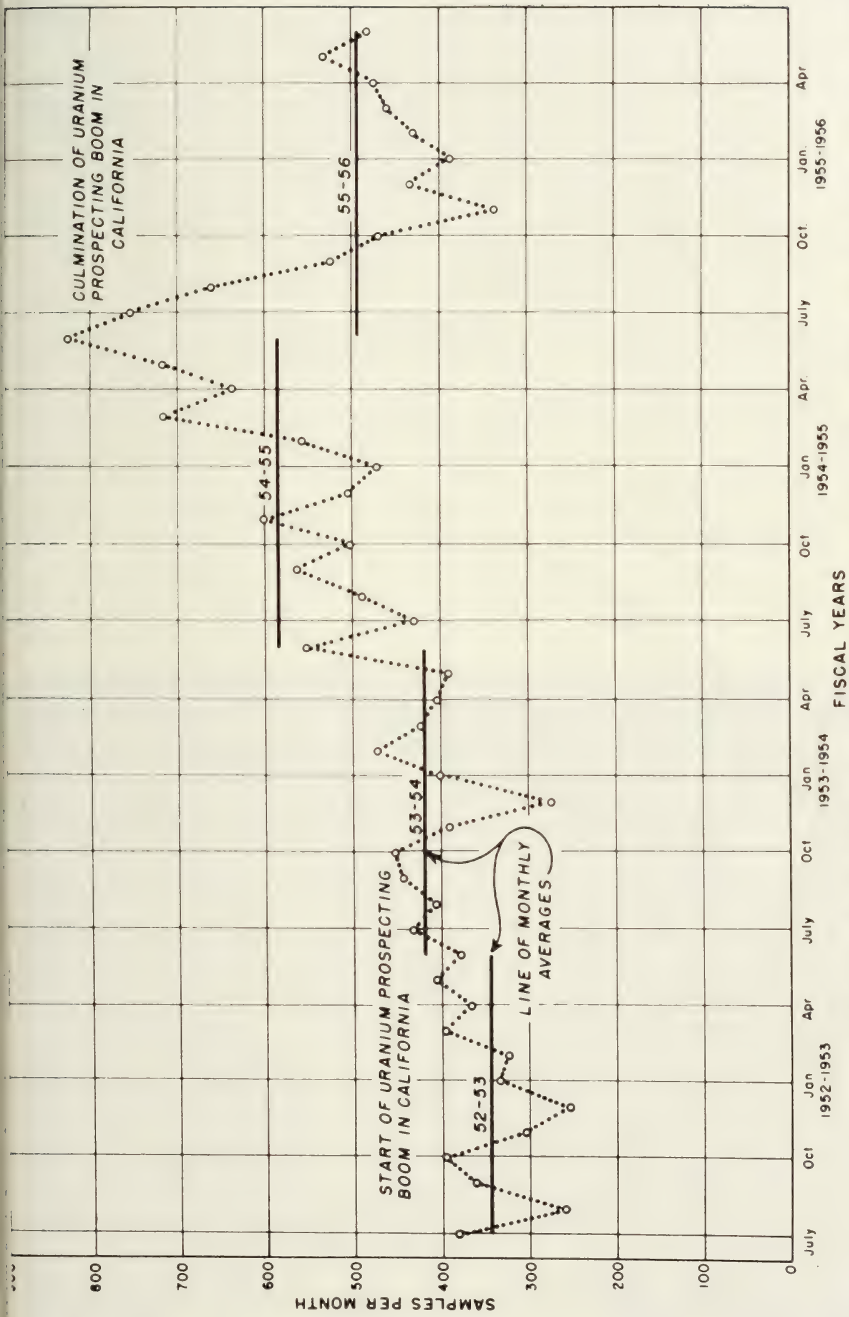

FIGURE 5. Mineral samples identified for the public by the laboratory of the Division of Mines during the last three fiscal years (1952 to 1956). Graph shows general uptrend in service, with uranium boom of 1954-55 reaching its highest point June, 1955.

whiteware was carried on for a staff investigator who collected several samples from large deposits in the desert areas of the state. Heretofore, only superficial testing had been done on the mineral materials which give much promise of becoming of great economic value. In order to do justice to this problem and to obtain additional data, the Laboratory should be broadly expanded, both in equipment and technical operation.

As a public service, the Laboratory makes only qualitative identifications of mineral samples submitted. Although many different types of mineral samples are received, the majority consist of various kinds of rocks (igneous, metamorphic, and sedimentary) and the silicate-type of nonmetallic minerals. If quantitative analyses are needed, the sender of the sample is referred to a private laboratory.

Only two samples per month are generally accepted from the sender since the present facilities and personnel are inadequate to handle any more than this number. The ordinary sample may require less than one hour for accurate identification and the preparation of a report for the sender; but frequently unusual rocks and mineral assemblages require much more time. As much as 8 hours have been spent identifying the minerals in a single ore specimen containing several related, yet complex minerals.

During the 1955-56 fiscal year, the staff of the Division laboratory identified 5,935 samples of ore, rock, and minerals submitted by the public. Although this figure represents a decrease of 15 percent over the previous fiscal year, 1954-55 (which was the all-time high), it is an increase of 16 percent over the fiscal year 1953-54, which was the

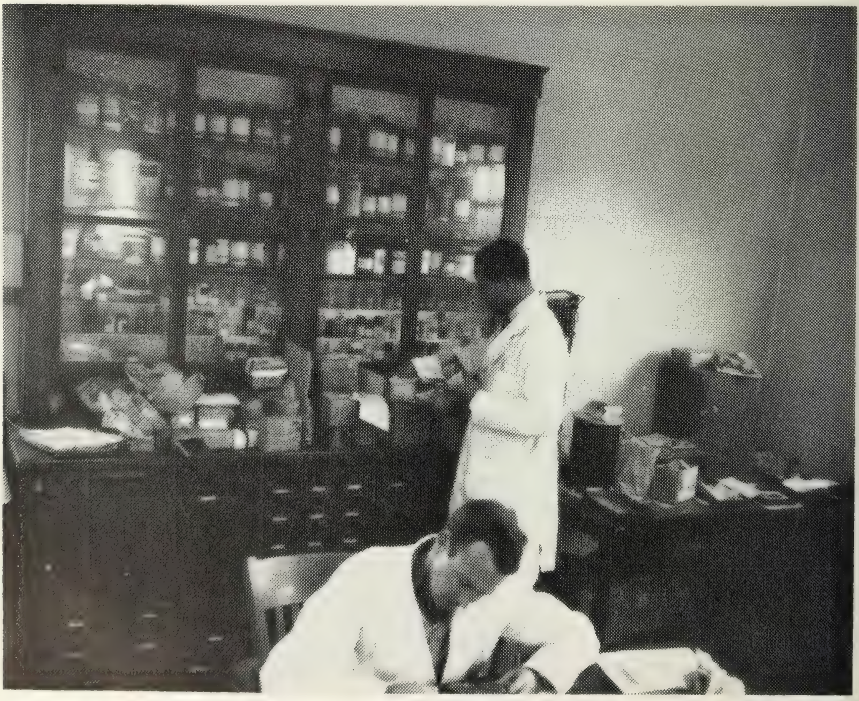

Figure 6. Mineral samples received by the laboratory for identification. *Photo by Mary Hill.*

highest record up to that time. The flood of samples received during the fiscal year 1954-55 was due to the uranium boom which was well under way in California as early as 1953, but which reached its peak in March 1955. The high record of this last year indicates a more serious interest in the development of the mineral industry, and the satisfaction of the senders of samples.

Although the search for fissionable materials has slackened off considerably, there is still an interest in uranium and thorium as indicated by the steady flow of incoming radioactive samples to the Division. The search for and interest in strategic minerals has not diminished. The search for chromium, manganese, nickel, copper, quicksilver, and tungsten, all important metallic ore minerals, has contributed much to the increase in samples.

The Division's Laboratory facilities were used extensively by staff members: The high temperature furnace, to determine the burning characteristics of ceramic white-ware raw materials and the expansion characteristics of perlites and shales useful as lightweight aggregates; the hydraulic press for briquetting test plates of ceramic whiteware raw materials; the sieves and shaking machine for making screen analyses of silica sands; the metallurgical polishing machine and microscope for studies of metallic ore minerals—in particular, specimens of massive sulfides; the petrographic microscopes, used in identifying rock and mineral samples; the differential thermal analysis apparatus, used for basic studies of serpentines and associated garnierite, clay minerals, and limestones; the spectrograph, used in qualitative and some quantitative spectrochemical analyses of minerals currently under investigation by staff members.

FIGURE 7. Visitors to the mineral exhibit. *Photo by Mary Hill.*

MINERAL EXHIBITS

Public Resources Code:

"2202. The State Mineralogist shall maintain offices, and a museum . . . in San Francisco for the purposes provided in this chapter."

"2205. The State Mineralogist shall: . . .

(c) Make a collection of typical geological and mineralogical specimens, especially those of economic and commercial importance, such collection constituting the museum of the Division.

(e) Make a collection of models, drawings, and descriptions of the chemical appliances used in mining and metallurgical processes."

"2206. The State Mineralogist may prepare a special collection of ores and minerals of California to be sent to or used at any world's fair or exposition in order to display the mineral wealth of the State."

Visual inspection of a mineral specimen, a rock, or a suite of ore minerals of common or rare metals, may be all that is necessary to answer certain questions of the public. The Mineral Exhibits of the Division, therefore, occupy an important position among the many public services rendered by the Division.

During the 1955-56 fiscal year, the Mineral Exhibits of the Division had 30,910 visitors. Of this total, 24,975 or 87 percent were adults, and 5,935 or 13 percent were children. There is a much greater attendance of children during the fall, winter, and spring months when the schools are in session. School children commonly visit the exhibits in groups of 30 or more and every effort is made by the curator to point out the many interesting features, especially those of current interest to the children of various grade levels.

Reclassification of the Mineral Exhibits according to the Dana system was continued, and by the end of the fiscal year, 24 cases had been completed and work was well under way on several more cases. In addition, one case of uranium minerals from California was completed. The model of the Calaveras cement plant, the stamp mill, the displays of fluorescent minerals, semiprecious and precious gemstones, gold, "Mineral of the Month," and mineral commodities are all attractions which not only commanded the attention of the visitors but their favorable comments.

A total of 499 sets of typical California minerals and rocks (called "schoolite sets" by the Division) was provided on request to elementary schools all over California. This service represents an increase of 42 percent over the previous fiscal year 1954-55. All requests for these sets were filled, including both pending and current. There has been an increase in the number of schoolite sets distributed each year during the past 10 fiscal years. This indicates the increased interest of the public schools in the rocks and minerals of California and the part they play in the geographic and economic development of the state.

MINERAL ACCESSIONS

Public Resources Code:

"2204. The State Mineralogist may receive on behalf of this State, for the use and benefit of the Division, gifts, bequests, devices, and legacies of real or other property and may use the same in accordance with the wishes of donors. If no instructions are given by the donors, the State Mineralogist shall manage, use, and dispose of the gifts, bequests, and legacies for the best interest of the Division and in such manner as he may deem proper."

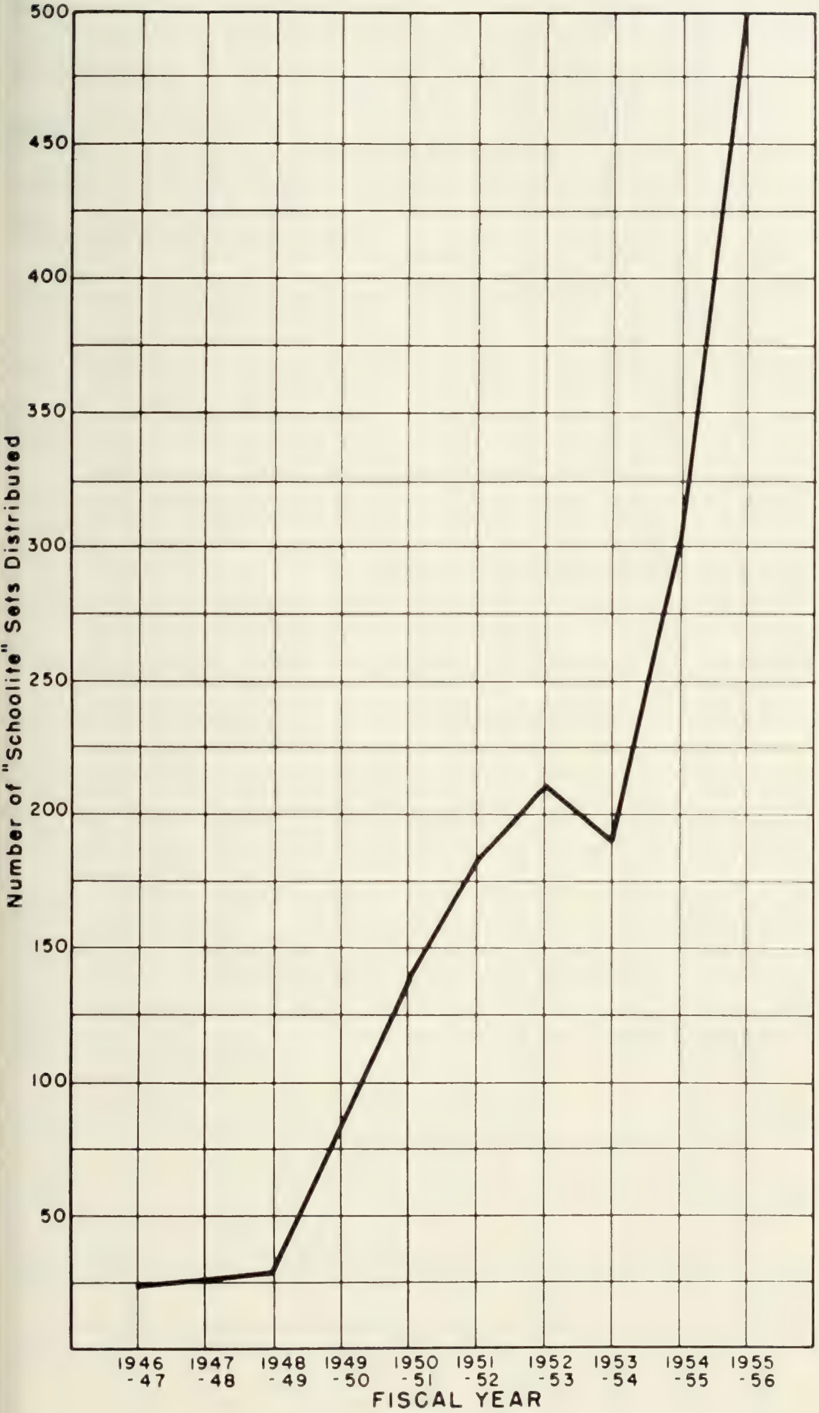

FIGURE 8. Distribution of mineral sets ("schoolite") by the Division of Mines to public schools in California. Graph shows rapid acceleration of services rendered during the last 9 years (1946 to 1956).

The following specimens were donated to the Mineral Exhibits of the Division of Mines during the 1955-56 fiscal year.

21588 Barite ($BaSO_4$), barium sulfate. From Barium Queen mine, San Bernardino County, California. Donor: C. J. Kundert, 1955.

21589 Barite ore ($BaSO_4$), barium sulfate. From Calico district, San Bernardino County, California. Donor: C. J. Kundert, 1955.

21590 Howlite ($Ca_2SiB_5O_9(OH)_5$), hydrated calcium silicoborate. From Sterling Borax mine, Tick Canyon, California. Donor: William Oke, 1955.

21591 Ulexite ($NaCaB_5O_9 \cdot 8H_2O$), hydrated borate of sodium and calcium. From Antofagasta, Chile. Donor: William C. Oke, 1955.

21592 Bastnaesite $(Ce,La,Di)(CO_3)F$., Fluo-carbonate of the cerium metals. From Mountain Pass, San Bernardino County, California. Donor: Molybdenum Corp. of America, 1955.

21593 Borax ($Na_2B_4O_7 \cdot 10H_2O$), hydrated sodium borate. From Boron, Kern County, California. Donor: William C. Oke, 1956.

21594 Inderite ($Mg_2B_6O_{11} \cdot 15H_2O$), hydrated magnesium borate. From Boron, Kern County, California. Donor: William C. Oke, 1956.

21595 Beta-inderite ($Mg_2B_6O_{11} \cdot 15H_2O$), hydrated magnesium borate. From Boron, Kern County, California. Donor: Wm. C. Oke Collection, 1956.

21596 Cinnabar (HgS), mercuric sulfide. From New Almaden Mines, Prudencia surface workings, Santa Clara County, California. Donor: Operated by Harry Mohley and Frank Thompson, 1956.

21597 Chromite ($FeCr_2O_4$), oxide of chromium and iron. From sec. 19, T. 8 N., R. 10 E., El Dorado County, California. Donor: Salem J. Rice, 1956.

21598 Navajoite ($V_2O_5 \cdot 3H_2O$), hydrated vanadium pentoxide. From Monument No. 2 mine, Monument Valley, Arizona. Donor: Hal Stephens, 1956.

21599 Corvusite ($V_2V_{12}O_{34} \cdot nH_2O?$), hydrous oxide of vanadium. From Uravan, Montrose County, Colorado. Donor: Hal Stevens, 1956.

21600 Hummerite, hydrous magnesium vanadate. From Hummer mine, East Paradox Mining District, Montrose County, Colorado. Donor: Peter Young, 1956.

21601 Hewettite, ($CaV_6O_{16} \cdot 9H_2O$), hydrated calcium vanadate. From Monument No. 2 mine, Monument Valley, Arizona. Donor: Peter Young, 1956.

21602 Methewettite ($CaV_6O_{16} \cdot 9H_2O$), hydrated calcium vanadate. From Hummer mine, East Paradox Mining District, Montrose County, Colorado. Donor: Peter Young, 1956.

21603 Rossite ($CaV_2O_6 \cdot 4H_2O$), hydrated calcium vanadate. From Bull Pen Canyon, San Miguel County, Colorado. Donor: E. H. Bailey.

21604 Andersonite ($Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$) hydrated carbonate of sodium, calcium and uranium. From Hillside mine, Arizona. Donor: Peter Young, 1956.

21605 Coffinite ($U(SiO_4)_{1-x}(OH)_{4x}$), uranous silicate. From Utah. Donor: Peter Young, 1956.

21606 Delafossite ($CuFeO_2$), copper iron oxide. From Richard mine, Kimberley, Nevada. Donor: J. McLaren Forbes, 1956.

21607 Zippeite ($(UO_2)_2(SO_4)(OH)_2 \cdot 4H_2O$), hydrated basic sulfate of uranium. From Dove Creek prospect, Montrose County, Colorado. Donor: Peter Young.

21608 Metazeunerite ($Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$), hydrated arsenate of copper and uranium. From Chilcoot area, Plumas County, California. Donor: P. L. Jones.

21609 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) hydrated vanadate of potassium and uranium. From near Adelanto, San Bernardino County, California. Donor: Laboratory.

21610 Cupresklodowskite (?), ($CuO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$), hydrous copper uranium silicate. From Chilcoot area, Plumas County, California. Donor: P. L. Jones.

21611 Autunite $(Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O)$ hydrated phosphate of calcium and uranium. From Kervin claim near Penyon Creek, Kern County, California. Donor: H. P. Kervin.

21612 Autunite $(Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O)$ hydrated phosphate of calcium and uranium. From Breckinridge area, Kern County, California. Donor: Laboratory.

21613 Schroeckingerite $(NaCa_3(UO_2)(CO_3)_3(SO_4)F\cdot 10H_2O)$ hydrated fluo-carbonate-sulfate of sodium, calcium and uranium. From northwestern Ventura County, California. Donor: Laboratory.

21614 Carnotite $(K_2(UO_2)_2(VO_4)_2\cdot 3H_2O)$ hydrated vanadate of potassium and uranium. From Loperna property near McKittrick, Kern County, California Donor: Laboratory.

21615 Carnotite $(K_2(UO_2)_2(VO_4)_2\cdot 3H_2O)$ hydrated vanadate of potassium and uranium. From Pennington claim near Parkfield, Monterey County, California. Donor: Laboratory.

21616 Carnotite $(K_2(UO_2)_2(VO_4)_2\cdot 3H_2O)$ hydrated vanadate of potassium and uranium. From Pennington claim near Parkfield, Monterey County, California. Donor: Laboratory.

21617 Gummite (?), $(UO_3\cdot nH_2O)$ hydrous uranium oxide. From Embree property, near Bodfish, Kern County, California. Donor: Laboratory.

21618 Uranophane $(CaO\cdot 2UO_3\cdot 2SiO_2\cdot 6H_2O)$ hydrated silicate of calcium and uranium. From Kramer Hills, San Bernardino County, California. Donor: Laboratory.

21619 Metatorbernite $(Cu(UO_2)_2(PO_4)_2\cdot 8H_2O)$ hydrated phosphate of copper and uranium. From Inyo County. Donor: Laboratory.

21620 Metatorbernite $(Cu(UO_2)_2(PO_4)_2\cdot 8H_2O)$ hydrated phosphate of copper and uranium. From east of Yosemite, Tuolumne County, California. Donor: Laboratory.

21621 Uranophane $(CaO\cdot 2UO_3\cdot 2SiO_2\cdot 6H_2O)$, hydrated silicate of calcium and uranium. From Jawbone Canyon, Kern County, California. Donor: Laboratory.

21622 Autunite $(Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O)$ hydrated phosphate of calcium and uranium. From Trinity County, California. Donor: Laboratory.

21623 Autunite $(Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O)$ hydrated phosphate of calcium and uranium. From Wakefield property, near Pozo, San Luis Obispo County, California.

21624 Carnotite $(K_2(UO_2)_2(VO_4)_2\cdot 3H_2O)$ hydrated vanadate of potassium and uranium. From near Masonic, Mono County, California. Donor: Laboratory.

21625 Uranophane $(CaO\cdot 2UO_3\cdot 2SiO_2\cdot 6H_2O)$ hydrated silicate of calcium and uranium. From near Niland, Imperial County, California. Donor: Laboratory.

21626 Tyuyamunite $(Ca(UO_2)_2(VO_4)_2\cdot nH_2O)$ hydrated vanadate of calcium and uranium. From near Adelanto, San Bernardino County, California. Donor: B. W. Troxel.

21657 Carnotite $(K_2(UO_2)_2(VO_4)_2\cdot 3H_2O)$ hydrated vanadate of postassium and uranium. From near Desert Center, Riverside County, California. Donor: Laboratory.

21628 Autunite $(Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O)$ hydrated phosphate of calcium and uranium. From Joanna No. 2 mine, near Blythe, Riverside County, California. Donor: Laboratory.

21629 Metatorbernite $(Cu(UO_2)_2(PO_4)_2\cdot 8H_2O)$ hydrated phosphate of copper and uranium. From San Bernadino County, California. Donor: Laboratory.

21630 Kasolite $(PbO\cdot UO_3\cdot SiO_2\cdot H_2O)$, hydrated silicate of lead and uranium. From east of Twentynine Palms, San Bernardino County, California. Donor: Laboratory.

21631 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From near McKettrick, Kern County, California. Donor: Laboratory.

21632 Carnotite ($K_2(UO_2)_2(VO_4)_2\cdot 3H_2O$) hydrated vanadate of potassium and uranium. From Knoll prospect, Verdi Development Company, Rosamond, Kern County, California. Donor: Laboratory.

21633 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Rosamond area, Kern County, California. Donor: Laboratory.

21634 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From near Olancha, Inyo County, California. Donor: Laboratory.

21635 Carnotite ($K_2(UO_2)_2(VO_4)_2\cdot 3H_2O$) hydrated vanadate of potassium and uranium. From near Placerville, El Dorado County, California. Donor: Laboratory.

21636 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Miracle mine, near Miracle Hot Springs, Kern County, California. Donor: Laboratory.

21637 Uraninite (UO_2) uranium oxide. From near Twentynine Palms, San Bernardino County, California. Donor: Laboratory.

21638 Uranophane ($CaO\cdot 2UO_3\cdot 2SiO_2\cdot 6H_2O$) hydrated silicate of calcium and uranium. From near Twentynine Palms, San Bernardino County, California. Donor: Laboratory.

21639 Uraninite (UO_2) uranium oxide. From near Twentynine Palms, San Bernardino County, California. Donor: Laboratory.

21640 Uraninite (UO_2) uranium oxide. From near Twentynine Palms, San Bernardino County, California. Donor: Laboratory.

21641 Carnotite ($K_2(UO_2)_2(VO_4)_2\cdot 3H_2O$) hydrated vanadate of potassium and uranium. From near Amboy, San Bernardino, California. Donor: Laboratory.

21642 Uraninite (UO_2) uranium oxide. From San Bernardino County, California. Donor: Laboratory.

21643 Uraninite (UO_2) uranium oxide. From Radium No. 1, Tuolumne County, California. Donor: D. W. Carlson.

21644 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Sonora Pass area, Tuolumne County, California. Donor: Laboratory.

21645 Beta-Uranotil ($CaO\cdot 2UO_3\cdot 2SiO_2\cdot 6H_2O$) hydrated silicate of calcium and uranium. From Inyo County, California. Donor: Laboratory.

21646 Gummite (?), ($UO_3\cdot nH_2O$) hydrated uranium oxide. From Bodega Head, Sonoma County, California. Donor: Laboratory.

21647 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From near Barstow, San Bernardino County, California. Donor: Laboratory.

21648 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Sunset claim near Taft in San Luis Obispo County, California. Donor: Laboratory.

21649 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Surprise Claim, near McKittrick, Kern County, California. Donor: Laboratory.

21650 Carnotite ($K_2(UO_2)_2(VO_4)_2\cdot 3H_2O$) hydrated vanadate of potassium and uranium. From Madonna Mia group near Chilcoot in Lassen County, California. Donor: Al Bertolini.

21651 Autunite ($Ca(UO_2)_2(PO_4)_2\cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From near Fellows in San Luis Obispo County, California. Donor: Laboratory.

21652 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) hydrated vanadate of potassium and uranium. From near Barstow, San Bernardino County, California. Donor: Laboratory.

21653 Autunite ($Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. Daybreak mine, near Spokane, Washington. Donor: Pacific Museum.

21654 Uraninite (UO_2) uranium oxide. From Utex mine, San Juan County, Utah. Donor: Albert S. Schneider.

21655 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) hydrated vanadate of potassium and uranium. From Grand County, Utah. Donor: Albert S. Schneider.

21656 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) hydrated vanadate of potassium and uranium. From Hazel Claims, Crooks Gap, Wyoming. Donor: L. J. Bergsten.

21657 Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) hydrated vanadate of potassium and uranium. From Easter Mine, Floriston, Nevada County, California. Donor: Laboratory.

21658 Autunite ($Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$) hydrated phosphate of calcium and uranium. From Siskon Mining Lease, near Doyle, Lassen County, California. Donor: Laboratory.

21659 Sabugalite ($HAl(UO_2)_4(PO_4) \cdot 16H_2O$) hydrated acid phosphate of aluminum and uranium. From Western Mining Corporation, Lease, near Doyle, Lassen County, California. Donor: Laboratory.

21660 Allanite ($(Ca,Ce,La,Na)_2(Al,Fe,Mn,Be,Mg)_3(SiO_4)_3OH$), basic silicate of calcium, iron, aluminum and cerium. From Pacoima Canyon, San Gabriel Mountains, Los Angeles County, California. Donor: Paul R. Brayton, 1956.

21661 Onyx ($CaCO_3$), calcium carbonate. From the Guadalupe Quicksilver mine, Santa Clara County, California. Donor: T. Orchard Lisle, 1956.

21662 Pyrite (FeS_2) iron sulfide. From the Bisbee Mines, Bisbee, Arizona. Donor: H. A. Vierthaler, 1956.

21663 Pyrite (FeS_2), iron sulfide on altered graywacke. From north end of the Tiburon Peninsula, Marin County, California. Donor: Mrs. Robert R. Redington, 1956.

21664 Guitermenite ($Pb_{10}As_6S_{19}$), a sulfide of arsenic and lead, with pyrite, hematite and sphalerite. From the Livingston mine, Custer County, Idaho. Donor: Ralph E. Mackay, 1956.

21665 Heulandite ($(Ca,NaK)_6Al_{10}(Al,Si)Si_{29}O_{80} \cdot H_2O$), hydrous silicate of calcium, sodium, potassium, and aluminum, with laumontite. From Sowerbutt quarry, Prospect Peak, New Jersey. Donor: T. Orchard Lisle, 1956.

21666 Uraninite (UO_2), uranium oxide. From Marysvale, Utah. Donor: Ben F. Blaine, 1956.

21667 Selenite ($CaSO_4 \cdot 2H_2O$), hydrous calcium sulfate, in twinned crystals. From Sheffield Reservoir, Santa Barbara, Santa Barbara County, California. Donor: Charles Benedette, 1956.

21668 Vermiculite, hydrous silicate closely related to the chlorites, but varying widely in composition. From the Old Dodge mine, Plumas County, California. Donor: H. E. Chaffee, 1956.

21669 Mercury (Hg), native, with cinnabar, metacinnabar, and terlinguate (?). From the Emerald Lake mine, near Redwood City, San Mateo County, California. Donor: F. F. Davis, 1956.

21670 Cinnabar (HgS), mercuric sulfide. From the Madrone mine, San Luis Obispo County, California. Donor: Victor V. Botts, 1956.

21671 Euxenite ($(Y,Ca,Ce,U,Th)(Cb,Ta,Ti)_2O_5$), a titanate-columbate of yttrium, calcium, cerium, uranium and thorium. Placer concentrate from Bear Valley, Idaho. Donor: V. A. Brusselo, Porter Brothers Corporation, 1956.

21672 Magnetite (Fe_3O_4) iron oxide. From near Crescent City, Del Norte County, California. Donor: Phyllis Bienick, 1956.

21673 Chromite ($FeCr_2O_4$), oxide of iron and chromium, coated with uvarovite and kotschubeite. From the Margaret mine, New Idris District, San Benito County, California. Donor: C. J. Leeper, 1956.

21674 Miargyrite ($AgSbS_2$), silver antimony sulfide. From the Kelley mine, Red Mountain, San Bernardino County, California. Donor: Wm. C. Oke, 1956.

21675 Garnierite ($H_2(Ni,Mg)SiO_4+H_2O$), hydrous silicate of magnesium and nickel Veinlets in serpentine. From Red Mountain, Del Norte County, California. Donor: Salem J. Rice, 1956.

21676 Torbernite ($Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$), hydrated phosphate of copper and uranium. From Mt. Spokane area, Washington. Donor: E. Katzer, 1956.

21677 Meneghinite ($Pb_{13}Sb_7S_{23}$), lead antimony sulfide, in limestone. From Johnson limestone quarry, Santa Cruz, Santa Cruz County, California. Donor: Norman Pendleton, 1956.

MINERAL COMMODITY PROGRAM

Bulletin 176. One of the most comprehensive projects yet to be undertaken by the staff of the Division of Mines has been the preparation of the forthcoming Bulletin 176. This will be a large volume summarizing all significant aspects of the mineral commodities that occur or are used in California. This volume has two principal purposes: (1) to provide concise descriptions of the nature, distribution, and abundance of the various mineral commodities in the state, and to compare these deposits with those that occur elsewhere in the United States and the world; and (2) to provide the prospector or owner of an undeveloped deposit with data on the perliminary recognition of useful minerals and rocks, and with marketing and specification information that will assist in an understanding of the problems involved in realizing a profit from a mining operation.

The preparation of these sections generally has involved (1) a thorough review of the literature on the commodities involved; (2) conferences and correspondence with persons familiar with the deposits, treatment, or marketing procedures; and (3) field investigations of deposits and utilization in California. Descriptions of out-of-state deposits were included wherever such information seemed desirable to bring the occurrences in California into proper focus, and wherever such out-of-state deposits contribute heavily to the mineral-consuming industries of California.

Nearly every member of the technical staff of the Division of Mines has contributed one or more of the 78 sections which will comprise this volume. It will have a large format, will contain about 500 printed pages, and will be well illustrated with location maps, geologic maps and cross-sections, flowsheets, and photographs. During the year 1955-56, 34 of these sections were submitted in preliminary manuscript form, and 25 were edited and revised to finished or nearly finished form.

The following list indicates the subject matter of each chapter of Bulletin 176 and the name of each staff author who has now become a commodity specialist:

Chapters and authors of forthcoming Bulletin 176, edited by Lauren Wright.

Chapters	Authors
1. Coal	Jennings
2. Natural gas	Hart
3. Natural gasoline, etc.	Hart

Chapters	Authors
4. Peat	Jennings
5. Petroleum	Jennings
6. Abrasive materials	Troxel
7. Andalusite, etc.	Wright
8. Arsenic	Goodwin
9. Asbestos	Rice
10. Asphalt and bituminous rock	Jennings
11. Barite	Kundert
12. Beryllium	Wright
13. Black sands	Stinson
14. Calcite (optical)	Wright
15. Carbon dioxide	Goldman
16. Cement	Bowen
17. Clay	Cleveland and Rogers
18. Diatomite	Oakeshott
19. Dimension stone	Goldman
20. Feldspar	Wright
21. Fluorspar	Chesterman
22. Gem stones	Wright
23. Graphite	Oakeshott
24. Limestone, dolomite, and lime products	Bowen
25. Magnesite, magnesium	Ver Planck
26. Mica	Wright
27. Nitrogen compounds	Ver Planck
28. Phosphates	Kundert
29. Pumice, pumicite	Chesterman
30. Pyrites	Chesterman
31. Pyrophyllite	Wright
32. Quartz crystal	Wright
33. Quartzite, vein quartz	Carlson and Clark
34. Salines (general)	Ver Planck
35. Boron	Ver Planck
36. Bromine	Ver Planck
37. Calcium chloride	Ver Planck
38. Gypsum	Ver Planck
39. Iodine	Ver Planck
40. Lithium	Ver Planck
41. Potassium salts	Ver Planck
42. Salt	Ver Planck
43. Sodium carbonate	Ver Planck
44. Sodium sulfate	Ver Planck
45. Sand and gravel	Gay
46. Shale (expansible)	Rogers
47. Specialty sands	Gay
48. Stone (crushed)	Gay
49. Strontium minerals	Ver Planck
50. Sulfur, sulfuric acid	Lydon
51. Talc and soapstone	Wright
52. Wollastonite	Troxel
53. Aluminum	Cleveland
54. Antimony	Goldman
55. Bismuth	Chesterman
56. Cadmium	Goodwin
57. Chromite	Rice
58. Cobalt	Chesterman
59. Copper	O'Brien
60. Gold	Clark
61. Iron	Gay
62. Lead	Stewart
63. Mercury	Davis
64. Manganese	Davis
65. Molybdenum	Stewart
66. Minor metals	Goodwin
67. Nickel	Rice
68. Platinum	Clark

Chapters	Authors
69. Rare-earths	Chesterman
70. Silver	Stewart
71. Tin	Gray
72. Titanium	Lydon
73. Tungsten	Stewart
74. Thorium	Troxel
75. Uranium	Chesterman and Troxel
76. Zinc	O'Brien
77. Zirconium and hafnium	Stinson
78. Vanadium	Stinson

Clay Survey. The Division's current clay program is successfully providing the public with useful basic information on the distribution, character, and utilization of ceramic raw products for industry in California. The work consists principally of geologic studies, and the results are eventually made available through publication, also by letter, telephone, and personal conversation. Examples of accomplishments for the year are as follows:

(1) A geologic map, on a scale of 2 inches to the mile, was prepared of the Alberhill area—one of the three most important clay localities in California.

(2) A preliminary report was completed on the distribution and properties of expansible shale in California.

(3) Geologic mapping and an evaluation of the clay resources was begun in the Little Antelope Valley area of southern Mono County.

(4) A general article on clay was prepared and published in *Mineral Information Service.*

(5) A series of papers on clay technology, presented before the Clay Industries Conference at the University of California, was edited by the Division and published in the April 1956 issue of *California Journal of Mines and Geology.*

(6) A comprehensive summary of the clay resources of California was written for the forthcoming Division's Bulletin 176.

(7) The Division presented a geologic report on the value and reserves of the high-grade clays, glass sands, and wax-producing lignites of the Ione area before the State Mining Board. The occasion required investigation of the government's plan to build certain dams which would cause this area and others, containing these valuable minerals, to be flooded.

(8) The Division maintained its active program with the University of California ceramics laboratory in the evaluation of new clay discoveries and in the study of established clay-producing areas. The Division's Bulletin 169, *Clays and Clay Technology,* has served a useful purpose in advancing the technical knowledge of clays throughout the whole country.

Peat and Coal Survey. A systematic study of peat and coal deposits in the state, which began two years ago, has produced new data for reports to be included in the Division's forthcoming Bulletin 176. The first map of its kind showing the locations of commercial peat deposits and the distribution of all peat bogs within the state has been compiled as one result of this study. Future plans in this field include a more detailed study and analysis of California lignitic coal suitable for extraction of wax. California has the only operating plant in the United

States which produces montan wax suitable for industrial purposes (a plant located near Ione, producing lignite from the Eocene Ione formation).

Talc Survey. In recent years, from 100,000 to 120,000 tons of talc have been mined annually in California and used principally in the manufacture of paint, wall tile, pottery, insecticides, and electrical insulators. Talc studies by the Division of Mines have been designed to document the nature and extent of these deposits, to determine the geologic processes by which they formed, and to gather data on the present or potential industrial uses of the various types of talcs in these deposits. These investigations have involved the preparation of geologic maps by means of a plane table or on topographic base maps. A total of about 150 deposits, mainly in eastern California, have been mapped or otherwise investigated. The usefulness of these studies was recently emphasized when a Division geologist indicated to claim owners the existence on their property of large deposits of commercial material, the value of which had gone unrecognized. These deposits have since been put into operation. In 1955-56 the talc data obtained thus far was tabulated and summarized by Lauren Wright as a contribution to a national talc resource report to be published by the U. S. Geological Survey and used by various federal defense-planning agencies. Such agencies are especially concerned about the availability of a type of high-purity talc, known as steatite, which is used in the manufacture of high-frequency electrical insulators. California has been the principal source of such talc.

Silica, Quartzite, and Specialty Sands Survey. The Division of Mines is currently making a survey of the quartz resources of California. Quartz is perhaps the earth's most common mineral; but in California, deposits of quartz suitable for commercial purposes that are also convenient to consuming centers are relatively scarce. The state's developing industries are requiring increasing quantities of quartz sand for glass manufacture and steel founding, crushed quartz for acid refractories and metallurgical processes, and ground quartz for ceramics and fillers.

A noteworthy example of the practical applications of the Division of Mines' basic geologic mapping was the opening, in 1955-56, of the first super-duty quartzite operation in California. In response to a request from a large ceramic concern for information on the occurrence of high-purity quartzite in California, a Division geologist recommended the Eureka quartzite, a formation in the Owens Valley area which had been mapped—and noted to be quite pure—by Division geologists working on the talc deposits of the area. The quartzite was subsequently tested by the ceramic company and found to be suited to the manufacture of the highest quality refractory silica brick, which is used mainly in the walls and roofs of open-hearth steel mills. During 1955-56, about 40,000 tons of this quartzite was quarried. The type of silica brick in which the quartzite is being used formerly was brought into California from the eastern United States, so that a new industry as well as a new industrial material has been established in the state.

Accelerated demand for high-purity quartz sands, principally used for glass manufacture and foundry molds, has led to a large number of requests of the Division for information. Established producers of specialty sands are seeking information concerning possible extensions of active and once-active deposits, as well as information leading to new deposits in other areas; several firms not previously producers of special sand desire information which may lead to development of new operations. The Division has already discovered and helped in the development of new deposits of high quality quartz sand in the foothill area of the Sierra Nevada.

Geologic mapping by Division geologists in the Corona South quadrangle, Riverside County, has aided materially in outlining the surface and underground limits of the formation that includes one of the state's most active and highest quality deposits of quartz sand. Much interest is shown by the industry in the possibility of similar geologic mapping projects by the Division in other areas where extensive but incompletely explored deposits capable of yielding high-quality specialty sand occur.

Gypsum and Salines Survey. The current expansion programs of several plaster manufacturers have created a lively interest in the gypsum resources of California and nearby states. The Division of Mines statewide survey of gypsum, published in 1952 as Bulletin 163, *Gypsum in California,* by W. E. Ver Planck, is proving to be a valuable aid to the public in the evaluation of gypsum deposits and properties. Other Division of Mines publications dealing with the saline and related commodities include Special Report 32, *Geological investigations of strontium deposits in southern California,* by Cordell Durrell, and Special Report 13, *Geology of the saline deposits, Bristol Dry Lake, San Bernardino County, California,* by Hoyt S. Gale.

The statewide survey of the salt industry in California has been completed by Ver Planck and is being processed for publication. Common salt is a valuable industrial raw material as well as an essential article in the home. The expanding chlorine-caustic industry of the Pacific Coast is largely supplied with salt from the San Francisco Bay operations by one of the world's largest producers of salt from sea water.

Limestone, Dolomite, and Cement Survey. During the past year the continuing statewide investigation of the limestone, dolomite, and cement raw materials resources of California included detailed studies of deposits in the Gabilan Peak area of Monterey and San Benito Counties and the Standard district southeast of Sonora, Tuolumne County. In addition to these two detailed projects, sampling of hitherto untested deposits was carried out at 19 localities in 13 counties. One hundred samples of limestone and dolomite were sent out for chemical analysis during the year. Requests for information on California limestone and dolomite deposits as well as for statistical and marketing information have shown a steady increase for several years, particularly with regard to deposits suitable for portland cement.

Use of limestone and dolomite in California has shown a steady increase in line with the expanding construction industry. The oftentimes unfulfilled demand for cement, particularly in southern California, has resulted in steady, marked expansion of most of the existing plants and in construction of two new plants—one at Mojave, Kern County, and one near Lucerne Valley, San Bernardino County. Demand for cement has been so great that capacities of both of these plants were scheduled to be nearly doubled before completion of the first units was realized. A very large, uniform deposit of limestone in the Argus

Range of southern Inyo County was put into production during 1955-56 to supply a chemical plant at WestEnd on Searles Lake. A number of concerns have shown particular interest in hitherto unused deposits in eastern San Diego and western Imperial County because of the rapidly expanding San Diego marketing area.

Rock Products (Crushed Rock, Sand and Gravel) Survey. The current boom in building construction and the recently enacted Federal Highway construction bill have focused much attention upon the resources of rock, sand, and gravel in the state. The Division is currently making a statewide survey and study of these resources, in particular the major stream deposits which furnish the bulk of the sand and gravel for concrete aggregate. A report is in progress on the aggregate resources of Cache Creek, an important source of materials used in the Sacramento Valley and in the construction of Monticello Dam near Winters. Geologic mapping and petrographic techniques are used to evaluate the extent and suitability of these deposits. Other state and federal agencies who have made intensive investigations of this nature are cooperating with the Division in furnishing unpublished reports that contain valuable technical data.

As a part of a re-survey of the mineral resources of Contra Costa and Alameda Counties, the Division is evaluating the resources of crushed rock, another important construction material necessary for development in the San Francisco area. The Division is also making a study of aggregate resources in the Los Angeles area and other parts of the state.

Nickeliferous Laterite Survey. Work continued on the Division's study of nickeliferous laterite deposits, a type of low-grade nickel ore first recognized and discovered in large areas in California as a result of the Division's geologic mapping program in the Klamath Mountains during 1952. These deposits are the result of residual enrichment of nickel in laterite, a type of soil developed from serpentine bedrock by intense chemical weathering. As far as is known they develop only under the influence of a tropical climate, such as prevailed in California during early Tertiary time. Reconnaissance mapping and preliminary surface sampling have established that remnants of nickeliferous laterite are widely distributed on early Tertiary erosion surfaces in the Klamath Mountains and foothills of the Sierra Nevada. Although current work is being concentrated in Del Norte County, where the greatest commercial potential appears to be, a preliminary report on the statewide occurrences of nickeliferous laterite is being prepared for publication.

Oil and Gas Surveys. Petroleum, natural gas, and natural-gas liquids constitute approximately four-fifths of the current value of California's mineral production. The Division of Mines serves this great petroleum industry for the most part by supplying information on basic geology, both local and regional, which is necessary in integration of the vast exploration program of the industry.

Publications of the Division which are in considerable demand by the oil and gas industry, and which were made available during the fiscal year 1955-56, are:

Bulletin 170, *Geology of Southern California*, Chaps. I-X, map sheets 1-34, and Geol. Guides 1-5, 1954. Collection of detailed and generalized papers concerning the various phases of geology and mineral industry, much of which applies to the petroleum industry.

Bulletin 171, *Earthquakes in Kern County, 1952*, 283 pp., 1955. Contains information on basic geology, faults, seismic prospecting, and seismology.

Bulletin 172, *Geology of the San Fernando quadrangle*, geologic and economic maps, structure sections (text not yet published), 1955. A detailed geologic map of an area of oil production and potential.

Special Report 44, *Bibliography of marine geology and oceanography, California coast*, 131 pp., 1955. Lists references on sedimentation, submarine topography, engineering problems, offshore oil, geophysics, and oceanography.

Special Report 45, *Exploratory wells drilled outside of oil and gas fields in California to December 31, 1953*, 104 pp., 1956. A compilation of exploratory wells giving location, dates started and abandoned, depth, and geology. Contains map (scale 1:1,000,000) and glossary of geologic units.

State geologic map, scale 1:250,000, 8 sheets available in preliminary form (Bakersfield, Death Valley, Long Beach, Los Angeles, San Luis Obispo, Santa Ana, Santa Maria, and Trona), 1955. Regional geology; all but two of these maps cover areas underlain by petroliferous strata.

In addition to serving the petroleum industry, the Division of Mines supplies information on oil and gas to land owners, planning commissions, consultants, and numerous other individuals and organizations not directly associated with the petroleum industry, as well as to other industries using mineral fuels and to the general public. For this purpose, resumé articles on oil and gas are frequently published as part of the county reports appearing in the *Journal of Mines and Geology*. Oil and gas sections are currently being prepared or are planned for reports on Orange, Tulare, Kern, Imperial, and Monterey Counties. Summary articles on petroleum, natural gas, and natural-gas liquids are currently being processed for the Division's forthcoming Bulletin 176. Articles of interest to the general public are published from time to time in *Mineral Information Service*. One such article on subsidence in the Wilmington oilfield recently appeared.

LOS ANGELES BRANCH OFFICE

During the fiscal year 1955-56, the staff of the Los Angeles branch office was engaged mainly in preparing, for publication, basic information on the occurrence and marketing of various mineral commodities in California. The total number of public services rendered in the office were not as great as those of the preceding year, but were considerably more than during 1953-54. The number of telephone calls and visitors to the Los Angeles office remains at a very high level. The decrease in public inquiries is attributable to a drop-off in public interest in uranium hunting. Such prospecting, which approached fad proportions during the period 1953-55, led to a depletion of a number of the Division's more popular publications which otherwise would have been available in 1955-56. This year, however, the staff was able to direct its attention to a much broader field of mineral commodities, especially those that contribute to the building and heavy construction industries which have grown so rapidly since World War II.

Office information services.

	1952-53	*1953-54*	*1954-55*	*1955-56*
Outgoing correspondence	3,599	3,526	4,467	3,225
Telephone calls	7,739	7,929	18,009	15,215
Visitors	5,630	7,540	19,004	13,187
Publication sales: Total pieces	5,386	7,001	12,924*	7,628*
Total value	$4,928	$7,433	$17,104*	$12,990*

* Includes sales at professional meetings in Los Angeles.

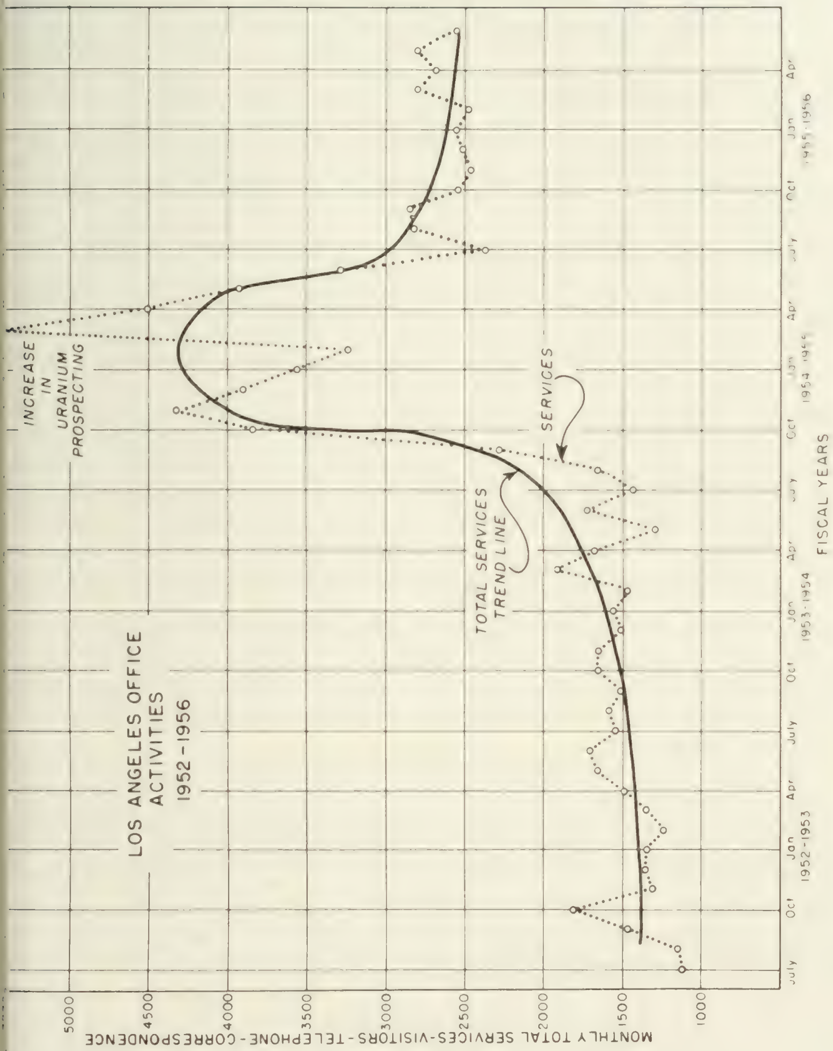

FIGURE 9. Graph showing growth of services in the Los Angeles office of the Division of Mines. Note that the demand for services has dropped after the uranium peak but is approaching a level about 67 percent higher than for the period immediately before.

In 1955-56 mineral commodity projects in the Los Angeles office were aimed mainly at the preparation of chapters for the Division's forthcoming Bulletin 176, which will be a comprehensive volume on the mineral resources of California and their utilization. By the end of the year, members of the Los Angeles staff had completed chapters on the following commodities: abrasive materials; kyanite, andalusite and related minerals; clay; feldspar; gem stones; mica; quartz crystal; sand and gravel; expansible shale; specialty sands; stone; talc and soapstone; wollastonite; aluminum; iron; lead; molybdenum; silver; tin; tungsten; thorium; and uranium. In addition, all of the contributions of other staff members were being edited in the Los Angeles office.

Other types of projects which occupied most of the remaining time of the Los Angeles staff members included (1) county report work (Kern and Orange Counties), (2) detailed geologic mapping of mineral deposits (i.e. clay deposits of Temescal Valley), (3) processing of reports contributed by geologists outside of the Division (i.e. Lake Elsinore report), (4) sampling and testing of mineral deposits (i.e. expansible shale and limestone), and (5) basic geologic mapping (i.e. southern Death Valley area and corona quadrangle). Staff members also attended and participated in meetings of various technical societies, mining groups, mineral shows, and fairs.

During 1955-56, a room was added to the Los Angeles office. This, together with improvements in the facilities for map displays and the acquisition of new office equipment, has greatly improved the working conditions for the local staff. A number of useful volumes were added to the Los Angeles office library which must necessarily be kept small and maintained selectively. It, therefore, continues to include only the books and periodicals of the types that are most frequently referred to by the public and staff members.

A complete set of the topographic quadrangles of California and files of other useful maps are maintained in Los Angeles office and are being constantly referred to. As many new maps of these types have been published in recent years, maintenance of adequate storage facilities is a constant problem.

One of the most noteworthy trends that continued through 1955-56 is an increasing spirit of cooperation and assistance which has developed between Division of Mines staff member and officials of mineral-producing and mineral-consuming concerns. For example, during the year, basic geologic information supplied by the Division of Mines was instrumental in the establishment of the first super-duty quartzite quarry in California. The potential and hitherto unrealized value of large deposits of tremolitic talc was indicated to claim owners.

SACRAMENTO BRANCH OFFICE

There was a continuing demand for the services of the Sacramento branch office during the 1955-56 fiscal year. The principal area of activity of this office is the Sierra Nevada and part of the Great Valley. This region contains a wide variety of rocks and minerals and is the source of a large number of commercial minerals. Increased population and industrial capacity of the Sacramento area has resulted in increased demand for raw mineral materials. There were several significant developments in the mining industry in this area during the past year: erection of a silica sand and clay plant at Camanche; installation of another cement kiln at San Andreas; the development of a new tungsten orebody at Grass Valley; reopening of several mines on the Sierran foothill copper belt; increased use of sand and gravel aggregates on the highways; and exploration for natural gas in the Sacramento Valley.

The number of office services decreased from the record of the fiscal year 1954-55 as a result of the drop in interest of the general public in uranium hunting, but increased over preceding fiscal years.

Office information services.

		1953-54	*1954-55*	*1955-56*
Outgoing correspondence		1,976	3,767	1,706
Telephone calls		803	2,121	1,657
Visitors		1,269	2,726	1,882
Publication sales:	Total pieces	986	1,761	1,075
	Total value	$1,207.50	$1,175.70	$1,036.15

The staff of the Sacramento office consists of two mining geologists and one non-technical employee. Office space consists of two adjoining rooms in State Office Building No. 1. Nearness to San Francisco enables the technical personnel to utilize the laboratory and library facilities at headquarters, major projects are carefully integrated with the headquarters and other branch offices.

Major active field projects of the Sacramento staff included a survey of the Sierra Nevada mining activities (71 active mines were visited); preparation of the Calaveras County report; and geologic mapping of the Mt. Abbot quadrangle. A report was completed on El Dorado County for publication in the *Journal*. A report on the Alleghany-Downieville lode gold mines was prepared and published in the *Journal*. A survey of activities along State Highway 49 was published in *Mineral Information Service*. Mineral commodity studies were made on gold, platinum, sulfur and sulfuric acid, titanium, and vein quartz and quartzite. Staff members were active at the Western Governors' Mineral Policies Conference, California State Fair, mineral shows, and several local societies.

REDDING BRANCH OFFICE

The Redding office serves as an information center for the general public and for engineers and geologists in government service and private practice interested in the mines, mineral deposits, and geology of northern California. Prospectors bring mineral samples for identification, and ask all manner of questions relating to their mining problems. The office is served by one mining engineer whose activities included completion of the Shasta County report, compiling chapters on copper and zinc for the revised edition of the forthcoming Bulletin 176, a table of mines for the Trinity County report, and a bibliography of published reports on 559 mining properties. Some current mining activities were checked in Shasta, Siskiyou, Tehama, and Trinity Counties.

Office information services.

		1953-54	*1954-55*	*1955-56*
Outgoing correspondence		973	1,185	1,192
Telephone calls		444	435	547
Visitors		1,098	1,428	1,075
Publication sales:	Total pieces	282	370	308
	Total value	$290.00	$257.00	$271.40

The decrease in the number of visitors is attributed to the loss of interest in prospecting for uranium, the approaching end of the government strategic minerals program, and the general high level of wages and employment.

The drop in interest in amateur prospecting was offset by an increase in the number of engineers and geologists in government and private employment who engaged in geologic and geophysical studies in the Shasta copper-zinc belt and in the area included within the government's Trinity River project. The Redding office library of publications describing the geology and the mines and mineral deposits in this area and map files were frequently consulted by professional engineers and others interested in mining, geology, and related subjects. The number of questions pertaining to locating and holding mining claims exceeded all others as usual and the *Legal Guide* continued to lead in sales of publications.

COOPERATION WITH OTHER STATE AGENCIES

The staff of the Division of Mines is occasionally called upon by other state agencies to provide special technical information, examples of which follow:

The Division was requested by the office of the Attorney General to have members of its staff available for calls for information concerning mines and mining operations. For example, such information is needed when the Attorney General's office is involved in claims filed on its basis of silicosis, against the state under the Subsequent Injuries Fund legislation.

Plans were developed with the Division of Forestry for a cooperative investigation of possible mineral resources in Mountain Home State Forest, Tulare County.

Frequent and important exchanges of information are made with the Division of Oil and Gas during informal staff interviews, including maps and reports, both published and unpublished.

The Division of Conservation Education is frequently provided with geologic information to be used in educational programs for the schools.

A staff member reviewed for the Water Pollution Control Board an application for construction of a custom concentrating mill in Riverside County and advised the local Board concerning the adequacy of methods proposed to prevent water pollution.

Frequent and important exchanges of information develop in informal staff interviews with the Department of Water Resources. Data relative to the compilation of the new state geologic map have been of particular interest. The Division of Mines is provided copies of all new topographic quadrangles issued by the U. S. Geological Survey in cooperation with the State Department of Water Resources.

Cooperation with the Division of Beaches and Parks has resulted in some published material. Long-range planning will undoubtedly involve more Division of Mines' staff time. Examples of assistance during prior years are cited below to show the type of information made available to the Division of Beaches and Parks.

1950-51. Conducted field investigations and prepared a report that was published as Special Report 11, *Guide to the geology of Pfeiffer-Big Sur State Park, Monterey County, California.*

1951-52. Conducted field investigations and furnished the Park museum at Big Basin State Park with a geologic map, a summary of the geologic history, photographs, sketches and specimens of fossils found locally, and specimens of the principal rock types of the area.

1953-54. Assisted in restoration of assay office, Wells Fargo Bank, Columbia Historic State Park.

1954-55. Conducted field investigations and prepared sketches of block sections illustrating the geologic history of the northern Coast Ranges for the Division of Beaches and Parks museum at Dyerville.

1955-56. Staff members assigned projects for field study and preparation of reports on Anza Desert-Borrego State Park, San Diego County, and Eureka Bowl-Johnsville area, Plumas County. Special emphasis is directed toward economic aspects of mineral deposits within these areas. These are specific examples of the type of requests that in the past have been made prior to acquisition of some areas by the Division of Beaches and Parks.

Preliminary studies were started that will lead to longer term projects involving geologic and mineral deposits investigations of many park sites, as outlined in the Five Year Master Plan for development of the State Parks system. The Division has been requested to prepare layman's guides to the geology of the various parks, and it is expected that this interesting program, especially helpful to the work of the Park Naturalist, may materialize.

REPORT OF THE U. S. GEOLOGICAL SURVEY ON COOPERATIVE STUDIES OF MINERAL DEPOSITS IN CALIFORNIA

(Fiscal Year 1956)*

By Paul C. Bateman

Geological investigations of mineralized areas in California by the U. S. Geological Survey, under a cooperation agreement with the California State Division of Mines, were carried on at the same scale as during the preceding year. The cost of the work, exclusive of supporting services, was about $70,000, which was shared equally by the State and Federal governments. Seven projects received cooperative support during the year. These were the Trinity River, Sierra Foothills, Eastern Sierra tungsten, Bishop tungsten, Darwin lead-zinc, Panamint Butte, and Panamint Valley gravity survey projects. Three of these projects—Trinity River, Sierra Foothills, and Eastern Sierra tungsten—received support for the entire fiscal year. Two projects, the Bishop tungsten and Darwin lead-zinc projects, were essentially completed and removed from the cooperative program before the end of the fiscal year; reports on these projects are in very late stages of preparation and will be completed at no further expense to the cooperative program. The Panamint Butte project, which adjoins the Darwin quadrangle on the east, and is in fact a continuation of the Darwin project, was begun late in the fiscal year. The Trinity River project, which was added to the cooperative program this fiscal year, was supported entirely in previous years by the Geological Survey. Gravity studies were carried out in support of the Eastern Sierra tungsten project and as a separate project in Panamint Valley. These gravity studies took only part of the fiscal year.

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* Publication authorized by the Director, U. S. Geological Survey.

Sierra Foothills Mineral Belt

The western Sierra Nevada foothills mineral belt is a region long famous for both gold and copper production. In recent years limestone and tungsten have been mined in increasing quantities, and other ores have been mined periodically. The mineral belt is more than 160 miles long, extending roughly from Mariposa to Oroville; it is approximately bounded on the east by the Sierra Nevada batholith and on the west by overlapping deposits of Tertiary age. Maps made many years ago and published in the Geologic Folios of the Mother Lode belt show the regional distribution of lithologic types, but the stratigraphy and structure of the belt were not completely worked out. The purpose of the present investigation is to determine the stratigraphic succession and structural history of the region and by the use of this new information to interpret the regional picture. The required data are collected by making detailed geologic maps along the major streams of the region. These streams cross the geologic structure and provide nearly continuous exposures. Internal structures of the rocks, clearly visible on stream-polished surfaces, indicate the tops of beds and are used in conjunction with sparse fossils to work out the structure and stratigraphy.

A report entitled ''Structure and stratigraphy of metamorphic rocks between the Merced and Cosumnes Rivers, California'' was almost completed at the end of the fiscal year. This report includes detailed maps and cross-sections along six major streams in an area about 85 miles long and 25 miles wide. A geologic map and block diagram presenting a synthesis of the structure based upon these sections and areal mapping by previous workers is included in the report. Field mapping of the second block to be covered by the project was begun with the mapping of the valleys of the Bear River and the Middle and North forks of the American River. A study of the petrography and a description of the Blue Canyon formation were begun in anticipation of a report on the second block.

Bishop Tungsten

The Bishop tungsten project terminated January 1, 1956. At the time of termination, a comprehensive report that deals with the economic geology, ''Economic geology of the Bishop District, California,'' has been transmitted to the Division of Mines for publication as Special Report 47, and preparation of a second comprehensive report that deals primarily with the regional geology and with more theoretical aspects of the tungsten deposits, to be published by the U. S. Geological Survey, was very nearly complete and will be finished as soon as possible.

The Bishop district is one of the most productive tungsten-bearing areas in the United States, having yielded more than a million units of WO_3 (tungsten trioxide) plus notable amounts of molybdenum, copper, gold, pumice, and perlite.

Eastern Sierra Tungsten

The Eastern Sierra tungsten project area includes five 15-minute quadrangles north and west of the Bishop tungsten district. Within it are active tungsten mines and unexploited deposits of tungsten, gold, silver, copper, lead, zinc, and iron, as well as deposits of kaolinite clay, perlite, pumice, and sand and gravel. The area is being mapped on a quadrangle basis, and reports are being prepared for each quadrangle as the mapping is completed. Two reports dealing with the Casa Diablo Mountain quadrangle, the first of the series to be completed, are in press. A report on the economic geology will be published by the California State Division of Mines as Special Report 48, and a report on the general geology will be published by the Geological Survey in its map series.

During the first few weeks of fiscal year 1956, a gravity survey of the Long Valley area, which occupies parts of the Casa Diablo Mountain and Mount Morrison 15-minute quadrangles, was conducted by the Geological Survey. Interpretation of the data provided by the gravity survey indicates that sediments fill the valley along the north and east sides to a depth of about 10,000 feet; this amount of fill required dip-slip displacement of as much as 13,000 feet along the normal fault that defines the eastern margin of the basin. The basin is one of the deepest ever discovered by gravimetric methods. The results of the gravity survey will be included in the U. S. Geological Survey's forthcoming report on the geology and ore deposits of the Mount Morrison 15-minute quadrangle.

This report was essentially completed during fiscal year 1956. During the year, the geologist's time was about equally divided between laboratory work and the actual writing of the report. Included in the report are descriptions of the metallic and non-metallic mineral deposits which have been explored or developed, and discussion, as well as representation by means of a geologic map, of areas favorable for the occurrence of undiscovered mineral deposits, particularly tungsten. The report also contains a comprehensive discussion of the general geology with particular emphasis on the stratigraphy of a roof pendant that contains locally fossiliferous metamorphic rocks, ranging in age from Early Ordovician to Triassic(?). The Ordovician rocks are the oldest that have been reported from the Sierra Nevada. The Paleozoic section consists of weakly metamorphosed fine-grained sedimentary rocks that are more than 30,000 feet in total thickness. The Triassic(?) section is more than 17,000 feet thick and consists of weakly metamorphosed volcanic tuffs, flows, hypabyssal intrusives, and a small amount of tuffaceous metasedimentary rocks.

Field work on the Devil's Postpile quadrangle, the next quadrangle to be mapped, will be started in July 1956.

Trinity River

The Trinity River project was begun by the U. S. Geological Survey early in 1953 as part of an inter-bureau study by the U. S. Department of the Interior of the drainage basins of the Lower Klamath, Trinity, and Eel Rivers. The purpose of the project was to prepare, by compilation of existing maps and field reconnaissance, a geologic map which would permit a more precise evaluation of the mineral resources of the area. The inter-bureau phase of the project was completed by July 1955, and resulted in a report entitled "The geology, mineral resources, and mineral industry of the Klamath, Trinity, and Eel River Basins, California." This report was prepared jointly with the U. S. Bureau of Mines, and is presently in press.

The project was timely from the standpoint of providing a geologic map of a large area, coincident with preparation of the new geologic map of California by the Division of Mines. However, a fairly large area south of the original project area remained unmapped, and the reconnaissance mapping supported by the cooperative program, was extended southward in fiscal 1956 to include parts of southern Mendocino and northern Sonoma counties.

The whole project area covers most of two geologic provinces, the northern Coast Ranges and the Klamath Mountains. The northern Coast Ranges are underlain dominantly by interbedded sedimentary and volcanic rocks of the Franciscan group of late Mesozoic age. The principal formations of the Klamath Mountains are mostly older than those of the Coast Ranges and range from Paleozoic to Mesozoic in age. The strata of both provinces have been intruded by mafic and ultramafic rocks that are locally serpentinized; and the strata of the Klamath Mountains have also been intruded by batholithic granitoid rocks.

The principal product of the study is a reconnaissance geologic map of the northern Coast Ranges and Klamath Mountains, an area equivalent to approximately eighty 15-minute quadrangles, of which more than half was mapped during the field reconnaissance. Although the mapping was not detailed, it has increased the knowledge of some of the broader features of the geologic history. A report now in preparation for publication by the U. S. Geological Survey describes the various rock formations, and contains a discussion of the metallic and nonmetallic mineral deposits of the area.

Darwin Lead-Zinc

Mapping of the regional geology and mineral deposits of the Darwin quadrangle was completed during fiscal year 1955. The quadrangle contains the Darwin mine—the most productive lead-silver-zinc mine in California—and the Talc City district, which has been this country's principal source of steatite-grade talc for the past 35 years. Early in fiscal year 1956 a report entitled ''Economic geology of the Darwin quadrangle, Inyo County, California'' was transmitted for critical review. This report, which is to be published by the California State Division of Mines as a Special Report, includes a comprehensive description of the geology and ore deposits of the Darwin lead-silver-zinc mine and descriptions of about 20 smaller lead-silver-zinc mines, 11 tungsten mines, 12 talc deposits, 1 antimony deposit, and 2 copper prospects.

A second report, which is nearly completed, is planned for publication by the U. S. Geological Survey. It includes detailed description of the stratigraphy and structure of the quadrangle as well as of the mineral deposits, with particular emphasis on a discussion of scientific problems in regard to the origin of the ore. A paper entitled ''Geology and ore deposits of the Darwin silver-lead district, Inyo County, California'' was presented to the American Institute of Mining, Metallurgical, and Petroleum Engineers, Southern California Section, at their October 1955 meeting in Los Angeles.

Panamint Butte

The Panamint Butte quadrangle adjoins the Darwin quadrangle on the east and is a unit in the mapping of a hundred-mile long belt of lead-silver-zinc districts in Inyo County that are being studied by the U. S. Geological Survey under the cooperative program. The north end of the Modoc district lies within the quadrangle, and several operating lead-silver mines are in the northeast part of the quadrangle in the Panamint Range.

Mapping was begun the last month of fiscal year 1955, and by the end of fiscal year 1956 half the quadrangle was mapped. In addition, large-scale maps were prepared of the surface and underground workings of the two principal mines. The rocks of Paleozoic age, which range in age from Ordovician to Permian, have been correlated with essentially similar rocks in the adjacent Darwin and Ubehebe Peak quadrangles. An interesting phase of the work will be a study of monolithologic breccias, which are extensively developed in the Towne Pass area.

Panamint Valley Gravity Survey

A gravity survey of Panamint Valley was supported in fiscal 1956 by the cooperative program of the California State Division of Mines and the U. S. Geological Survey. Field work, conducted during the winter field season by a four-man gravity crew, consisted of establishing 214 gravity stations in the Darwin, Panamint Butte, Maturango Peak, Telescope Peak, Trona, and Manly Peak quadrangles. The gravity data were reduced to the simple Bouguer anomaly as the field work progressed.

The objective of the gravity survey is to compile a complete Bouguer anomaly map of Panamint Valley and adjoining parts of the surrounding mountain ranges. The data will then be interpreted in terms of regional structural trends and the disposition, thickness, and structure of the rocks of Cenozoic age. The area covered by the survey adjoins the Searles Lake basin, Death Valley, and Owens Valley gravity surveys, and the scheduled Saline Valley and Indian Wells Valley gravity surveys. The gravity network of the Panamint Valley survey is tied to the adjoining surveys, the Mojave Desert and southern Sierra Nevada surveys, and to the U. S. Coast and Geodetic Survey pendulum network.

An inspection of the simple Bouguer anomaly map reveals the general character of the anomalies, but no detailed interpretation can be made until very large terrain corrections have been computed. A gravity low of moderate relief with the lowest point near the center of the Panamint Valley lies in the Revenue Canyon-Knight Canyon area. The low is not confined to the valley but extends over the Tertiary outcrops north of Wildrose Canyon. To the north, the anomaly diminishes gradually, but to the south opposite Ballarat it is terminated rather abruptly. Along the northeast margin of the Slate Range a gravity low, about 5 miles long by 2 miles wide and with a gravity closure of more than 5 milligals, aproximately parallels the front of the range. Gravity highs occur over all areas where rocks older than Tertiary are at or near the surface. In the western part of the Darwin quadrangle the gravity values show a marked decrease toward Owens Valley and the Sierra Nevada.

MINES AND MINERAL RESOURCES OF EL DORADO COUNTY, CALIFORNIA

BY WILLIAM B. CLARK * AND DENTON W. CARLSON **

OUTLINE OF REPORT

Page
Abstract 370
Introduction 371
Geology 373
  Structure 373
  Rock units 374
  Intrusive rocks 376
  Geologic history 377
Mines and mineral resources 379
  Metallic minerals 379
    Chromite 379
    Copper 393
    Gold 400
      Lode deposits 401
      Placer deposits 429
      Seam deposits 435
    Iron 437
    Lead 437
    Manganese 437
    Molybdenum 437
    Nickel 438
    Platinum-group metals 438
    Quicksilver 438
    Radioactive minerals 438
    Silver 439
    Titanium 439
    Tungsten 439
    Zinc 440
  Nonmetallic minerals 441
    Asbestos 441
    Clay 441
    Dimension stone 441
    Dolomite 442
    Gems and ornamental minerals 442
    Limestone 443
    Mineral paint 452
    Silica 452
    Slate 453
    Soapstone 455
    Stone 457
Bibliography 460
Tabulation of El Dorado County mineral deposits 463

Illustrations

Plate 9. Geologic map of El Dorado County In pocket
10. Map of western El Dorado County showing mines and mineral deposits In pocket
11. Map of eastern El Dorado County showing mines and mineral deposits In pocket
Figure 1. Photo showing greenstone near Placerville 374
2. Photo showing Mariposa slate near Kelsey 376
3. Photo showing Cascade Lake 377
4. Photo showing topography of high Sierra 378

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Page
Figure 5. Map of western El Dorado County showing distribution of serpentine and chromite-bearing areas 384
6. Flowsheet, El Dorado Co. chrome mill 386
7. Geologic map of Flagstaff Hill area showing chromite deposits 388
8. Photo showing Pillikin chrome mine 389
9. Mill flowsheet of Pillikin Mining Co. chrome mill at Pioneer-Lilyama mine 390
10. Photo showing El Dorado copper mine 395
11. Photo showing Volo mill 397
12. Volo mill flowsheet 399
13. Longitudinal map of underground workings, Alhambra gold mine 402
14. Composite map of underground workings, Alhambra gold mine 403
15. Map of underground workings, Alpine gold mine 405
16. Map of underground workings, Beebe gold mine 407
17. Cross-section of underground workings, Black Oak gold mine, showing veins 410
18. Mill flowsheet, Grit gold mine 416
19. Mill flowsheet, Hazel Creek gold mine 417
20. Map of underground workings, Hazel Creek gold mine 418
21. Sketch map of El Dorado County showing Tertiary river channels 430
22. Sketch map of Placerville area showing locations of former placer mines and Tertiary gravel deposits 432
23. Photo showing limestone quarry of California Rock and Gravel Company 444
24. Photo showing lime plant of Diamond Springs Lime Company 446
25. Photo showing limestone quarry of Diamond Springs Lime Company 447
26. Photo showing El Dorado Limestone Company plant 448
27. Cross-section of shrinkage stope employed by El Dorado Limestone Company 449
28. Photo showing plant of Semon Lime Company 450
29. Photo showing mine and crushing plant of Pacific Minerals Company 454
30. Photo showing State Division of Highways sand pit near Coloma 458
31. Photo showing Harms sand and gravel pit at Coon Hollow 459

ABSTRACT

El Dorado County lies within the northern portion of the Sierra Nevada, chiefly on the west slope. Coloma, on the American River, was the site of James C. Marshall's gold discovery of 1848. Soon afterward thousands of gold seekers arrived to work the streams. Mining, lumbering, agriculture, and vacation and resort services are the major industries of the county.

Rocks exposed in El Dorado County range from Paleozoic to Recent in age. The entire county is underlain by the Bedrock Series of the Sierra Nevada. This series consists of steeply dipping, intensely folded and faulted metamorphic rocks of Paleozoic and Mesozoic age that have been invaded by several types of igneous rocks, chiefly granitic. Associated with the intrusion of the igneous rocks was the formation of gold, silver, copper, and chrome deposits. Over the bedrock are nearly flat-lying gold-bearing gravels and volcanic and sedimentary rocks of Tertiary age. Glacial moraines of Pleistocene age cover large portions of the higher Sierra in eastern El Dorado County. Lake Tahoe was formed by faulting during the Tertiary time.

From 1880 to 1953, the total mineral output of the county was $57,122,787. Gold has been the most important single mineral commodity produced, followed by limestone and limestone products. The most productive gold mines are on the Mother Lode belt. Gold also has been produced from the East and West gold belts. The Mother Lode gold belt is a system of northwest-trending gold-bearing quartz veins that traverses the central portion of the county. The seam gold deposits in the north end of the county have been worked by both placer and hardrock methods. Major Mother Lode gold mines in the county include the Union, Pacific, Beebe, Sliger, and Church mines. Seam deposit at Georgia Slide were highly productive.

East Belt gold veins are smaller but usually richer than those of the Mother Lode. Noted East Belt gold mines include the Mount Pleasant, Alhambra, and the Hazel Creek, the last being the principal source of gold in the county. West Belt deposits are low grade but usually quite large. Among the more productive West Belt mines were the Big Canyon, Zantgraf, Crystal, and Shaw.

Substantial quantities of gold were produced from Eocene channel deposits in hydraulic and draft mines, particularly in the Placerville area. Other channels were worked east of Georgetown, Grizzly Flat, and Indian Diggings. During the 1930's, many Recent stream gravels were worked by dragline dredges.

There are a number of extensive deposits of crystalline limestone in the county. At present, the El Dorado Limestone Company and the California Rock and Gravel Company produce limestone for use in the beet sugar industry. These concerns also ship limestone to the Diamond Springs Lime Company, for use in the manufacture of chemical and metallurgical lime. Lime also is produced at the Semon Lime Company plant near Rattlesnake Bridge. For many years limestone was produced from the Cool-Cave Valley deposit for use in cement manufacturing.

Large quantities of chromite have been produced at the Pillikin mine, which was active until 1955. Also active until 1955 were several custom chrome mills. Chromite also has been mined from deposits in the Latrobe and Georgetown areas.

Copper has been produced from the foothill copper belt and as a by-product of gold mining. At present, copper ore from Amador County is concentrated at the Volo mill near Placerville. Silver, lead, and zinc have been produced as by-products from gold and copper mining.

Tungsten prospects recently have been found east of the Mother Lode. At present a prospect near Grizzly Flat is under development. Other metals found in El Dorado County include iron, manganese, molybdenum, nickel, platinum, and quicksilver.

Slate is mined at Chili Bar. It is fine-ground and marketed as roofing material. Dimension slate was produced from several nearby properties many years ago. Soapstone is mined near Latrobe, milled in the San Francisco Bay area, and marketed as an insecticide carrier. Rhyolite tuff is quarried east of Placerville and used as ornamental stone in home construction.

Sand and gravel are mined near Placerville. Crushed rock is produced south of Placerville for use as asphalt mix. Broken granodiorite has been used as rip-rap on various roads in the county. Sand and limestone are mined for use as road metal.

INTRODUCTION

El Dorado County is in the north portion of the Sierra Nevada. It is bounded on the north by Placer County, on the west by Sacramento County, on the south by Alpine and Amador Counties, and on the east by part of Alpine County and the State of Nevada. In 1850, it was created as one of California's original 27 counties. El Dorado County was named from the Spanish phrase meaning ''The Gilded One.''

History. Coloma, the scene of Marshall's historical gold discovery, is on the South Fork of the American River 8 miles northwest of Placerville. In 1847, John Sutter, the grantee and almost feudal baron of a large Mexican land grant at what is now Sacramento, signed a contract with James Marshall to erect and operate a sawmill on the American River. The mill was under construction late that year. It then was decided to enlarge the tailrace to allow more water to run off. On the morning of January 24, 1848, while inspecting the tailrace, Marshall noted a yellow flake in shallow water and picked it up. After testing it for malleability, other flakes were obtained. These were taken to Sutter's Fort where more tests were applied. The tests proved beyond a doubt that gold had been discovered.

Sutter and Marshall tried to keep the discovery a secret. However, word leaked out from several sources, and soon it was known in Benicia and San Francisco. The first published announcement of the discovery of gold appeared in the San Francisco newspaper *The Californian* on March 15, 1848. Among the first miners to arrive at the scene of discovery were Mexicans from Sonora who previously had worked placers in Los Angeles County. Soon afterward, thousands of gold seekers arrived in El Dorado County and spread out in all direction in the Sierra

Nevada. Shallow placers in nearly every stream in the western part of the county were worked at this time. Lode mining began in El Dorado County in 1851 at Nashville.

Towns such as Nashville, Spanish Flat, Grizzly Flat, Chili Bar, Fairplay, and Diamond Springs sprang up. Placerville, which was variously known as Old Dry Diggins and Hangtown, was incorporated in 1854. In 1850, El Dorado County was founded as one of the original 27 counties in California. During the 1850's, it was one of the most populous counties in the state. In 1855, the Sacramento Valley Railroad, the first rail line in California and now part of the Southern Pacific system, was built to connect Sacramento and Shingle Springs. Later it was extended to Placerville. During the Comstock Lode boom of the 1860's and 1870's, the county prospered from the Placerville wagon and stage road, which followed along what is now U. S. Highway 50. The road was one of the main routes from San Francisco to Virginia City. Another well-traveled route of those days was the wagon and stage road, which ran east along the Rubicon River via Georgetown, Wentworth Springs, and Rubicon Springs, and terminated at Lake Tahoe.

With the decline of the Comstock mines, the economy of El Dorado County became more diversified. Lumbering, fruit growing, and stock raising became important. Later, with the improvements made in transportation facilities, vacation and resort services increased greatly, especially in the Lake Tahoe area. Interest in the numerous landmarks including the preserved and restored buildings of the old gold mining camps also has accounted for an increase of tourists in the county.

Industries. Lumbering is the largest industry in El Dorado County. According to the El Dorado County Chamber of Commerce, approximately $16,000,000 worth of lumber and lumber products were produced in the county in 1952. Resort and vacation services, the second largest source of income in the county, accounted for more than $7,500,000 in 1952, while agricultural production totaled $4,069,000. The main agricultural products are fruit, livestock, and poultry. Placerville is the chief agricultural center of the county. In 1953, the mineral output of the county totaled $1,992,069.

The principal lumber-producing areas are in the central and east-central portions of the county. Large sawmills are at Camino, Diamond Springs, Georgetown, Omo Ranch, Pacific House, and Shingle Springs, and there are several logging field camps that are moved from time to time. Until recently two of the major concerns were served by narrow-gauge logging railroads. One extended from Camino northeast to Pino Grande and the other southeast from Diamond Springs to Caldor.

For many years the Lake Tahoe region has been a popular resort area. Noted resorts are at Stateline, Bijou, Al Tahoe, Meeks Bay, and Camp Richardson. Echo and Fallen Leaf Lakes also are popular vacation areas.

Geography. El Dorado County lies within the Sierra Nevada, most of it being on the western slope. It has an area of 1,725 square miles, 44 percent of which was owned by the Federal Government in 1950. Elevations range from 350 feet above sea level in the western foothills to 10,881 feet at Freel Peak in the extreme eastern portion of the county. Other prominent peaks in the county which are along the eastern Sierran crest are Job's Sister (10,823 feet), Monument Peak (10,085 feet), Pyramid Peak (9,983 feet), and Mount Tallac (9,725 feet).

The principal streams in the county are the west-flowing American, Rubicon, and Cosumnes Rivers, all of which have cut deep precipitous canyons. One-fourth of Lake Tahoe, the largest lake in the Sierra Nevada, is in the east portion of El Dorado County. Other large lakes in the county are Fallen Leaf, Echo, Aloha, and Loon.

Placerville, which had a population of 3,726 in 1950, is the county seat and the largest town. Other towns in the county include Camino, Coloma, Diamond Springs, El Dorado, Georgetown, Shingle Springs, Pollock Pines, Al Tahoe, Tahoe Valley, and Bijou.

U. S. Highway 50 traverses the central portion of the county in an easterly direction. Also the county is served by State Highway 49, which trends north via Placerville; State Highway 89, which runs north along the west border of Lake Tahoe; and State Highway 88, which runs east along the southern border of the county from Cook's Station to Peddler Hill. There are a number of county roads, many of which are paved. Also there are a number of privately owned logging roads.

The county is served by the Southern Pacific Railroad, which runs via Latrobe, Shingle Springs, Diamond Springs, and terminates at Placerville. A lumber railroad runs from Placerville to Camino.

GEOLOGY

El Dorado County is underlain predominantly by crystalline rocks of Mesozoic and Paleozoic age. Metasediments of the Paleozoic Calaveras group underlie nearly a third of the county, and granitic rocks roughly another third. Jurassic metasediments and metavolcanics and Tertiary volcanic and detrital rocks underlie most of the remaining area. The strongly folded Paleozoic and Mesozoic metamorphic rocks, together with the granitic rocks and serpentine intruding them, have been conveniently grouped together under the term "Bedrock series." The Tertiary rocks, which have been laid down upon the upturned edges of the older metamorphic rocks, are commonly grouped together under the term "Superjacent series." The Superjacent series is generally flat-lying or else very gently dipping in contrast to the steeply dipping Bedrock series.

Structure

Structure of the metamorphic and intrusive igneous rocks making up the Sierran bedrock complex is not always clear. Structure sections accompanying the U. S. Geological Survey folios for El Dorado County show a series of beds of metamorphic rocks with continuous easterly dips broken only by intrusions. However, the metamorphic beds actually are a complicated series of folds that have been heavily faulted. By separating the Amador group, Taliaferro has been able to work out the intricate structure of the bedrock west of the Mother Lode in southwestern El Dorado County along the Cosumnes River (Taliaferro, 1943, pp. 285, 306). The repetition of beds of Mariposa slate and greenstone, especially north of Placerville, are results of this intricate folding.

The Mother Lode vein system was formed in fissures that developed within a zone of reverse faulting. The zone trends north and in El

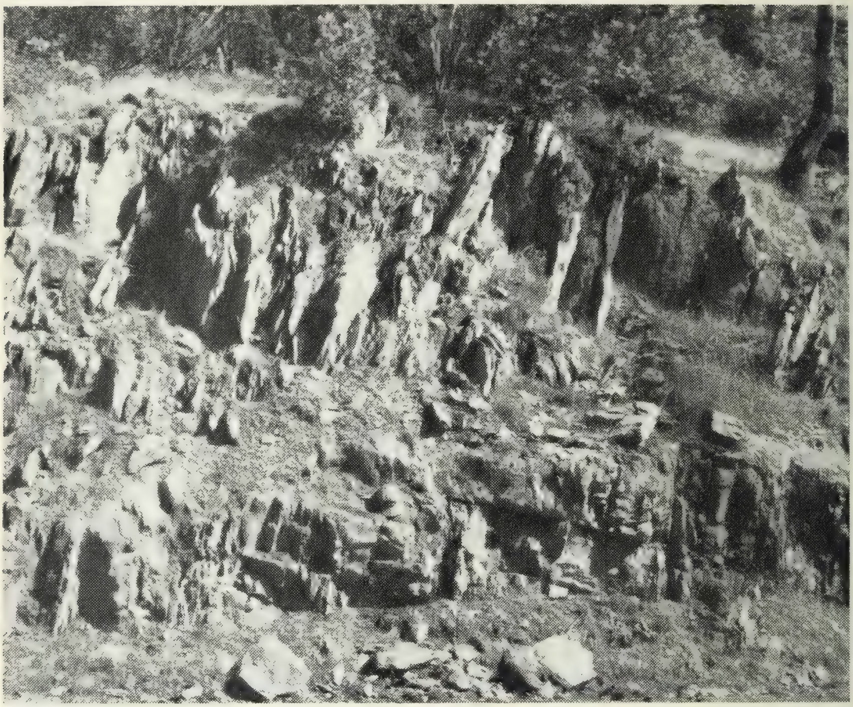


FIGURE 1. Greenstone showing schistose structure, in roadcut north of Placerville.

Dorado County is in Mariposa slate. In most areas the displacement is unknown, but to the south in the upper part of the Argonaut mine in Amador County, the measured displacement of beds along the fault fissure is 120 feet (Knopf, 1929, p. 67). At Garden Valley, the Mother Lode system splits into two branches, one extending north through Georgetown and the other northwest through Greenwood.

The ultrabasic intrusions, which now are largely serpentinized, trend north-northwest and reflect the major structural trend of the region. The acidic batholithic masses were intruded after the beds had been folded (Taliaferro, 1943, p. 285).

Major faulting along the east flank of the Sierra Nevada has had a profound influence on the later geologic history of the county. Faulting occurred on the east flank during the end of the Miocene and at the beginning of the Pliocene epoch, and the Sierra Nevada was elevated and became asymmetrical in form with a broad western slope and a short eastern slope (Hinds, 1952, p. 18). Between this fault zone and the Carson Range in Nevada a section sank, forming the basin now partly occupied by Lake Tahoe. During the end of the Pliocene and beginning of the Pleistocene this deformation was renewed on a major scale.

Rock Units

Calaveras Group (Carboniferous to Permian). The Calaveras group is an undifferentiated suite of metamorphic rocks ranging chiefly from Carboniferous to Permian in age—the oldest known rocks in the county.

It is found in two general areas, one east and one west of the Mother Lode. East of the Mother Lode, it consists of a succession of beds of black clay slate, metamorphosed sandstones, quartzite, and mica schist with scattered lenses of crystalline limestone (Lindgren and Turner, 1894, p. 3). West of the Mother Lode the succession consists of highly compressed black slate and sandstone with some chert and meta-chert, and several limestone lenses. Coral and crinoid debris is present in portions of the limestone. Several small tactite bodies have been developed in rocks of the Calaveras group.

Undifferentiated Metamorphic Rocks (Triassic to Jurassic). West and southwest of Lake Tahoe on both sides of the Sierran crest are detached masses of slate, schist, quartzite, and greenstone. Because of their position in what is possibly a continuation of the Sailor Canyon formation, which lies to the north, these rocks have been classified as Triassic to Jurassic in age (Lindgren, 1896, p. 5).

Greenstone and Metasediments (Partly Upper Jurassic). This group occupies an extensive part of the west portion of El Dorado County. It includes rocks which have been mapped as amphibolite, metadiabase, and hornblende porphyrite, as well as rocks of the Amador group of Upper Jurassic age (Taliaferro, 1943, p. 284). The type section of the northern part of the Amador group crops out along the Cosumnes River in southwestern El Dorado County. It is divided into two formations, the Cosumnes below and Logtown Ridge above. The Cosumnes formation consists of sheared sandstone, slate, and a thick basal conglomerate. The Logtown Ridge formation is composed of massive porphyritic augite andesite and coarse andesitic agglomerate.

Mariposa Formation (Upper Jurassic). The Mariposa formation crops out as a north-trending belt that passes through Placerville, and as a northwest-trending belt along the west border of the county. The formation consists of dark clay slate in uniform and nearly vertical beds. Small cross-bedded sandstone lenses are found locally in the slate.

Auriferous Gravels (Tertiary). The most extensive gold-bearing gravel deposits of Tertiary age in the county are those of the Tertiary South Fork of the American River in the Placerville area. The gravel is composed of pebbles and boulders of quartz, chert, granitic and volcanic rocks interbedded with clay and sand. Considerable amounts of placer gold are present near or at the base of these deposits.

Valley Springs Formation (Middle (?) Miocene). Flat or nearly flat beds of the Valley Springs formation are found in and east of Placerville. They consist predominantly of light to buff-colored rhyolite tuff. The tuff usually is fine grained and contains small crystals of black biotite. Smaller amounts of breccia, conglomerate, and siltstone are present.

Mehrten Formation (Upper (?) Miocene and Pliocene (?)). The Mehrten formation, occupying many of the interstream ridges in the east-central portion of the county, consists chiefly of volcanic debris composed of boulders, cobbles, pebbles, and, in some places, angular

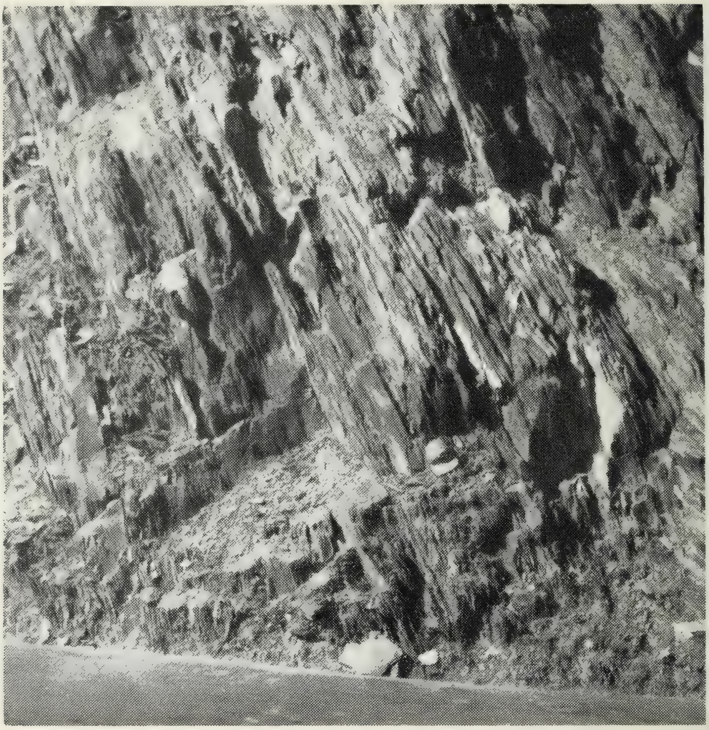


FIGURE 2. Slate of the Mariposa formation exposed in a roadcut near Kelsey.

fragments of porphyritic andesite mingled with volcanic ash and some sandy detritus of non-volcanic origin. A few flows of massive andesite are exposed in the eastern portion of the county.

Basalt (Pleistocene). Several lava flows of early Pleistocene age cap some of the ridges in eastern El Dorado County. They are composed of dark fine-grained olivine basalt.

Glacial Moraines (Pleistocene). Extensive moraines deposited by Pleistocene glaciers are west and south of Lake Tahoe. They are composed of exceedingly rough angular boulders of all sizes mixed with sand and gravel and finer detritus.

Alluvium (Quaternary). Sand and gravel deposited in lake beds, and sand, silt, and gravel in and adjacent to present stream channels make up the Quaternary alluvial deposits.

Intrusive Rocks

Serpentine and Associated Rocks. In the western portion of the county are a number of north- to northwest-trending serpentine bodies. Present in them are smaller amounts of pyroxenite, peridotite, and dunite, and it is from these rocks the serpentine is derived. Considerable amounts of gabbro, which is associated with serpentine are present in some areas (Cater and others, 1951, p. 115). These rocks were intruded prior to the emplacement of the granitic rocks.

Granitic Rocks. Extensive bodies of granitic rock occupy much of the eastern portion as well as several areas in the western portion of the county. Granodiorite is the predominant rock type. However, granite, diorite, and quartz porphyry as well as rocks that have been classified as gabbrodiorite by Lindgren and Turner (Lindgren and Turner, 1894, pl. 2) are included in this group.

FIGURE 3. Cascade Lake and Mount Tallac, Lake Tahoe area. Camera facing south.

Geologic History

During late Paleozoic time, El Dorado County was covered by a vast open sea. Large amounts of sediments that later gave rise to the various metamorphic rocks of the Calaveras group were deposited. These included mud, sand, calcareous ooze, and chemically deposited silica containing manganese. Toward the end of the Paleozoic era, a crustal disturbance destroyed part of the sea basin, partially folded the sedimentary rocks, and created a land area of unknown extent.

The sea again advanced over what is now the Sierra Nevada. Toward the end of the Jurassic period sedimentary and volcanic rocks including pillow basalts and breccias were deposited at the bottom of this sea. Part of this series is commonly called the Amador group. Marine deposition of fine-grained sediments of the Mariposa formation followed.

In late Jurassic time, orogenic processes completely changed the character of the Sierra Nevada. There was an almost complete withdrawal of the sea. The already folded Paleozoic rocks and nearly flat-lying

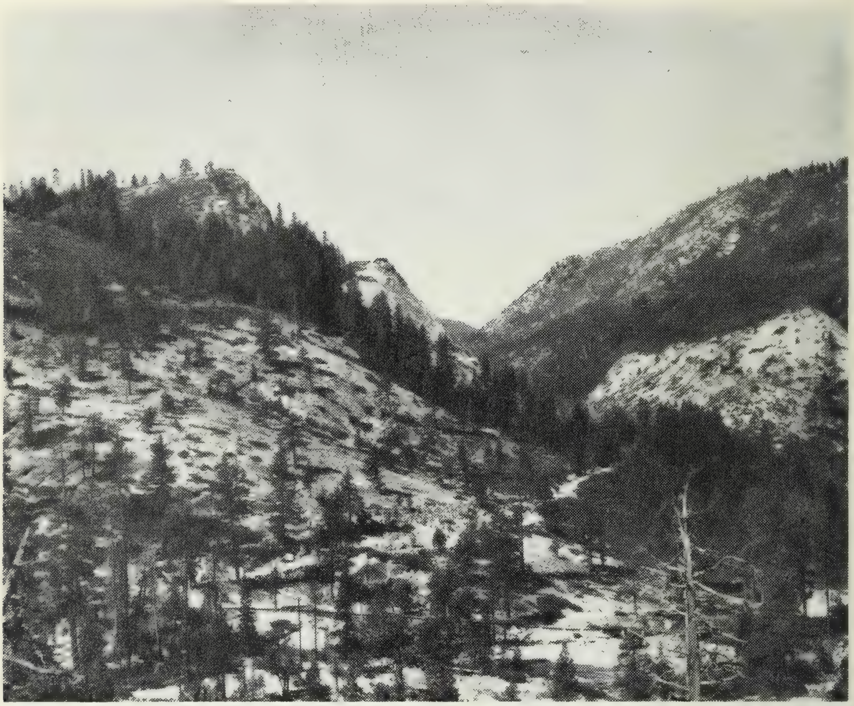


FIGURE 4. High Sierra topography, shaped by glacial action. Lovers' Leap and canyon of the upper South Fork of American River. Camera facing west.

Mesozoic rocks were intensely folded and faulted into a series of complicated northwest-trending folds, and the rocks themselves were metamorphosed. Fine-grained sedimentary rocks were changed to slate, siliceous sediments to quartzites and metacherts, volcanic rocks to amphibolite and chlorite schist and greenstone, and calcareous sediments to crystalline limestone.

Before the complete destruction of the sea basin, the area was intruded by ultrabasic rocks. Chromite, which was present in the ultrabasic rocks, was concentrated by magmatic segregation. Most of these rocks subsequently were altered to serpentine. Soon afterward a sequence of granitic rocks was emplaced on a major scale beginning with the more basic types and followed by the more acidic varieties. Copper and zinc were deposited in what is now the lower Sierran foothills. Gold and silver with some copper and lead were deposited in quartz veins deep within the folded crust. Some tungsten and copper deposits were formed in contact metamorphic zones near the borders of the granitic bodies.

A very long period of erosion followed during Cretaceous time. The rocks lying above the gold deposits were stripped away, and the gold-bearing veins themselves were cut deeply. The elevation of the old Sierra Nevada was greatly reduced, and broad river valleys developed. Near the end of the Cretaceous period, the sea advanced again to the west margin of the ancestral Sierra Nevada. Thin marine deposits of Cretaceous age lie just to the west of El Dorado County.

By Eocene time, the Sierra Nevada had been worn down greatly. The climate at this time was subtropical, and there was much chemical decay of the bedrock. Deposits of clay, quartz, sand, and lignite were formed along the margins of the Eocene sea west and south of El Dorado County. Gold and other weather-resistant material, such as quartz pebbles from the veins, were concentrated in streams as placer deposits. Some of these Eocene placers were unusually rich in gold.

Volcanic activity began in the Sierra Nevada at or near the close of the Eocene epoch. Rhyolite ash fell in the lower elevations, while higher up in the mountains both flows and ash falls were deposited. The stream channels were choked and the drainage system completely changed. The new stream channels that developed were characterized by deposits containing abundant rhyolite pebbles. These deposits are known as the ''inter-rhyolite gravels.'' After the close of the emission of rhyolite, the volcanoes began to emit andesitic lavas. Only near the summit of the range are massive andesite flows found, the greater part of the Sierran slope being covered by extensive mud flows, the first containing sands and clays, the later containing great quantities of andesite fragments. The streams again were forced into new channels, depositing what is known as the ''interandesitic gravels.'' These intervolcanic channels commonly were leaner in gold than the Eocene channels. Volcanic activity reached its climax in late Miocene or early Pliocene times.

The basin now partly occupied by Lake Tahoe developed as a depressed fault block by dislocations occurring during Miocene-Pliocene times. Two principal faults, one east and one west of the lake evolved. Several times in the past Lake Tahoe was of greater size and depth than it is now.

In late Pliocene or early Pleistocene time, the Sierra Nevada was re-elevated on a major scale. This was accomplished by faulting along the east flank. The west-flowing rivers and streams cut deep canyons in the newly uplifted area and removed much of the volcanic cover. The Tertiary channel deposits were exposed and subjected to erosion. Stripping of the gold lodes continued. Glaciers appeared in the higher elevations of the Sierra during the Pleistocene epoch. In El Dorado County they occupied extensive areas west and south of Lake Tahoe and elaborately carved the topography of this region. Echo, Fallen Leaf, and Loon Lakes were formed by glacial action. The glaciers retreated in early Recent time, and the present climate and topographic features developed.

MINES AND MINERAL RESOURCES

Metallic Minerals

Chromite

El Dorado County contains the largest known chromite deposits in the Sierra Nevada. The total recorded production of chromite for the county is about 40,000 tons. Estimated reserves are about 600,000 tons of material containing at least 5 percent chromic oxide (Cater and others, 1951, p. 119). The largest deposits are at the Pillikin mine in the Flagstaff Hill area in the western portion of the county. The bulk of the total chromite production of the county has been from this mine. Other chromite-bearing areas are in and near serpentine bodies in the Latrobe, Clarksville, Webber Creek, Pilot Hill, Garden Valley, *Summary of economic geology of El Dorado County.*

Geologic age		Rock units	Rock types	Mineral deposits
Quaternary	Recent	Alluvium	Silt, sand, gravel	Placer gold, platinum, sand and gravel
Tertiary	Pliocene	Mehrten	Andesitic detritus	Building stone
	Miocene	Valley Springs	Rhyolite tuff	Building stone, aggregate, manganese
	Eocene	Auriferous gravel	Gravel, some clay and sand	Placer gold, platinum, gravel, quartz, clay
Messozoic	Jurassic	Veins	Vein quartz	Gold, silver, copper, lead, zinc, quartz
		Tactite (silicated limestone)	Tactite	Tungsten, copper, gold, silver
		Granitic rock	Granodiorite, granite, diorite, gabbro, etc.	Riprap, road metal, sand, building stone
		Serpentine	Serpentinized peridotite, pyroxenite, gabbro, etc.	Chromite, asbestos, road metal, soapstone
		Mariposa	Slate	Slate
		Greenstone and metasediments	Metavolcanic rocks, some metasediments	Building stone, aggregate
Paleozoic	Permian Carboniferous	Calaveras group	Metasandstone, slate, quartzite, mica schist, metachert, crystalline limestone	Limestone, marble, manganese, slate

Table 1. Mineral production of El Dorado County, 1880-1953.

Year	Gold value	Silver value	Copper		Lime		Limestone		Slate		Miscellaneous stone		Miscellaneous and unapportioned	
			Pounds	Value	Tons	Value	Tons	Value	Squares	Value	Value	Amount	Value	Substance
1880	$389,383	$208					[1]							
1881	550,000	900												
1882	600,000													
1883	530,000													
1884	575,000	16,000												
1885	35,000													
1886	619,992	1,822												
1887	706,871	365												
1888	650,000	500												
1889	427,638	408												
1890	204,583	275												
1891	173,279	359												
1892	198,321													
1893	294,610	1,220												
1894	366,707	356			1,600	$8,000			1,800	$11,700				
1895	700,101	448			4,560	28,500			1,350	9,450				
1896	812,289	534			706	4,158			500	2,500				
1897	674,626	886			2,160	6,750	500	$250	400	2,800				
1898	501,966	4,174			538	3,360			400	2,800				
1899	404,497	8,414			1,270	7,935			600	4,500				
1900	368,541	25,129	3,125	$500	1,200	6,000			3,500	26,250			$251,820	Unapportioned, 1900-09.
1901	292,036	5,977			1,760	11,000			5,100	38,250				
1902	335,031	52	2,128	319	3,936	16,176			4,000	30,000				
1903	277,304				896	7,000								
1904	474,994				2,058	7,075			6,000	50,000		10 tons	162	Asbestos.
1905	384,735	2,525	160,000	24,960	1,482	6,946	1,050	5,775	4,000	40,000		112 tons	2,625	Asbestos.
1906	431,746	2,690			3,075	21,138			10,000	100,000		20 tons	1,000	Asbestos.
1907	319,177	2,301		122	1,782	16,198	5,394	15,318	7,000	60,000				
1908	342,033	5,504	603	83	2,547	20,192			6,000	50,000	$1,600	200 M	8,000	Paving blocks.
1909	238,284	1,299			2,212	14,591			6,961	45,660	530	3,763 tons	5,645	Sand (glass).
1910	171,304	967			1,808	9,944			1,000	8,000	2,616	1,200 tons	1,800	Sand (glass).
1911	133,967	1,010			2,414	12,309	1,000	1,000			5,465	3,701 lbs.	167	Lead.
1912	105,565	843			2,244	11,218					4,375			
1913	62,688	250	696	107							4,678			
1914	133,886	654			2,240	12,082					2,600	90 lbs.	4	Lead.
1915	401,288	1,353	417	73	2,546	12,872					7,500		5,250	Slate and soapstone.
												5,260 tons	72,560	Chromite.
1916	361,821	1,496	[3]		[3]		[3]				12,000		19,613	Lime and limestone.
												886 tons	1,717	Silica.
													1,480	Copper and soapstone.
1917	24,758	85	18,982	5,182	[3]		[3]				6,200	8,319 tons	167,950	Chromite.
													104,851	Lime and limestone.

Table 1. Mineral production of El Dorado County, 1880-1953—Continued.

Year	Gold value	Silver value	Copper		Lime		Limestone		Slate		Miscellaneous stone		Miscellaneous and unapportioned	
			Pounds	Value	Tons	Value	Tons	Value	Squares	Value	Value	Amount	Value	Substance
1918	28,352	722	22,259	5,498	----	----	96,673	218,120	----	----	----	2,684 tons	4,506	Silica.
													70	Other minerals.
											20,500	11,936 tons	674,856	Chromite.
													11,236	Pyrites, silica, soapstone.
1919	30,121	279	----	----	----	----	41,025	112,423	----	----	----	378 tons	6,510	Chromite.
											1,700	1,600 tons	13,950	Soapstone and talc.
													1,169	Other minerals.
1920	13,379	155	----	----	----	----	----	139,873	----	----	5,500	2,640 tons	18,200	Soapstone.
													9,325	Other minerals.
1921	34,109	301	----	----	----	----	15,296	66,143	----	----	2,750	1,652 tons	9,453	Talc.
1922	47,340	376	----	----	----	----	42,200	113,700	----	----	4,250	----	18,850	Slate and soapstone.
1923	30,264	185	----	----	----	----	95,274	163,987	----	----	5,900	2,670 tons	15,729	Soapstone.
												1,498 tons	8,988	Talc.
1924	28,207	153	----	----	----	----	112,156	322,955	----	----	2,538	----	32,691	Copper and lime.
1925	40,212	238	----	----	----	----	228,293	297,127	----	----	10,305	----	4,946	Lime and silica.
1926	91,789	472	----	----	[3]	----	59,386	186,702	[3]	----	17,510	----	5,613	Lime, silica, slate.
1927	82,254	383	[3]	----	----	----	96,733	146,506	[3]	----	500	----	15,792	Copper, gems, silica, soapstone, slate.
													8,855	Soapstone.
1928	122,017	697	1,074	155	----	----	57,012	158,252	[3]	----	17,455	365 tons	21,995	Lead, silica, slate.
1929	57,680	236	[3]	----	[3]	----	71,033	199,989	[3]	----	25,665	----	83,930	Copper, lime, silica, slate, soapstone.
1930	78,019	250	----	----	[3]	----	88,869	205,225	[3]	----	96,599	----	113,105	Lead, lime, silica, slate, soapstone.
1931	85,322	283	[3]	----	[3]	----	79,798	207,594	[3]	----	37,494	----	107,242	Chromite, copper, lead, lime, silica, slate, soapstone.
1932	182,043	438	850	54	[3]	----	105,094	207,241	[3]	----	[3]	----	97,126	Lead, lime, platinum, silica, slate, soapstone, miscellaneous stone, tungsten ore.
1933	540,989	1,458	2,755	176	[3]	----	120,026	208,049	[3]	----	7,551	----	90,586	Lead, lime, slate, soapstone.
1934	1,380,710	6,035	4,312	345	8,250	85,938	112,237	152,422	[3]	----	7,400	----	18,405	Lead, silica (quartz), slate, soapstone.
1935	1,803,368	5,943	12,391	1,028	[3]	----	151,814	298,867	[3]	----	46,886	----	232,907	Lead, lime, mineral water, silica (quartz), slate, soapstone.
1936	1,988,735	9,063	21,661	1,993	[3]	----	159,134	348,055	[3]	----	77,778	----	371,356	Chromite, lead, lime, mineral water, platinum, slate, soapstone.
1937	1,719,795	8,238	65,353	7,908	[3]	[3]	227,721	448,130	[3]	----	20,784	[3]	402,762	Chromite, lime, mineral water, platinum, slate, soapstone.

1938	1,484,805	5,717	40,535	3,972	[3]	------	135,142	304,420	[3]	--	64,202	-----	343,983	Chromite, lead, lime, mineral water, soapstone, slate.
1939	2,520,105	8,627	10,910	1,135	[3]	------	146,625	320,212	[3]	------	16,422	4,766 lbs.	224	Lead.
													410,954	Chromite, lime, platinum, mineral water, slate, soapstone.
1940	1,341,585	3,799	1,630	184	[3]	------	261,713	308,708	[3]	------	12,947	------	427,272	Chromite, lead, lime, slate, soapstone.
1941	1,577,630	4,216	957	113		------	75,631	152,390	[3]	------	9,241	------	580,574	Chromite, lead, lime, slate, soapstone.
1942	636,790	1,624	[3]	------	------	------	147,469	247,522		------	15,396	------	418,918	Chromite, copper, lead, platinum, slate, soapstone.
1943	5,040	303	20,282	2,637	------	------	[3]	--		[3]	------		296,469	Chromite, lead, limestone, slate, soapstone, miscellaneous stone.
1944	2,870	574	52,648	7,109	------	------	------	[3]		[3]	[3]		288,306	Chromite, limestone, lead, slate, miscellaneous stone.
1945	23,660	791	45,284	6,113	------	------	------	[3]		[3]	[3]		271,063	Chromite, lead, limestone, slate, soapstone, miscellaneous stone.
1946	95,305	1,065	------	[3]	------	------	248,402	578,136		[3]	101,170		62,558	Copper, lead, slate, soapstone.
1947	104,790	1,845	112,000	23,520	--	[3]		[5]		[3]	[5]483,991		1,026,874	Lime, sand and gravel, slate, soapstone, lead and zinc.
1948	90,720	1,259	72,000	15,624	------	[3]		[5]		[3]	[5]490,086		1,161,110	Lime, sand and gravel, slate, and soapstone.
1949	108,990	712	------	------	------	[3]	--	[5]		[3]	[5]440,674		999,648	Lime, sand and gravel, slate, and soapstone.
1950	135,100	713	------	------	------	[3]		[3]		[3]	[3]		1,694,889	Lime, limestone, sand and gravel, stone, slate, soapstone.
1951	132,230	996	3,700	895	------	[3]		[3]		[3]	[3]	--	1,896,610	Limestone, lime, slate, stone, soapstone, lead, sand and gravel.
1952	206,675	1,901	------	------	------	[3]	166,106	498,927		[3]	[3]		1,276,524	Chromite, lead, lime, sand and gravel, slate, miscellaneous stone, and soapstone.
1953	260,085	2,655	158,000	45,346	------	[3]		[3]		[3]	113,772	--	1,570,211	Chromite, lead, lime, limestone, slate, soapstone, zinc.
GRAND TOTALS	$31,385,106	$161,706	834,562	$155,151	51,284	$329,382	3,148,806	$6,634,018	58,611	$481,910	$2,204,530	------	$15,770,984	

Grand total value, $57,122,787.

(1) Until 1938, a large tonnage of limestone was shipped annually from El Dorado County for use in cement manufacture. Value of this material was included in the state total for cement.

(2) Includes crushed rock, rubble, riprap, sand, gravel.

(3) See under **Unapportioned**.

(4) There was small production of quicksilver in the 1860's, but no record of amounts.

(5) Includes limestone.

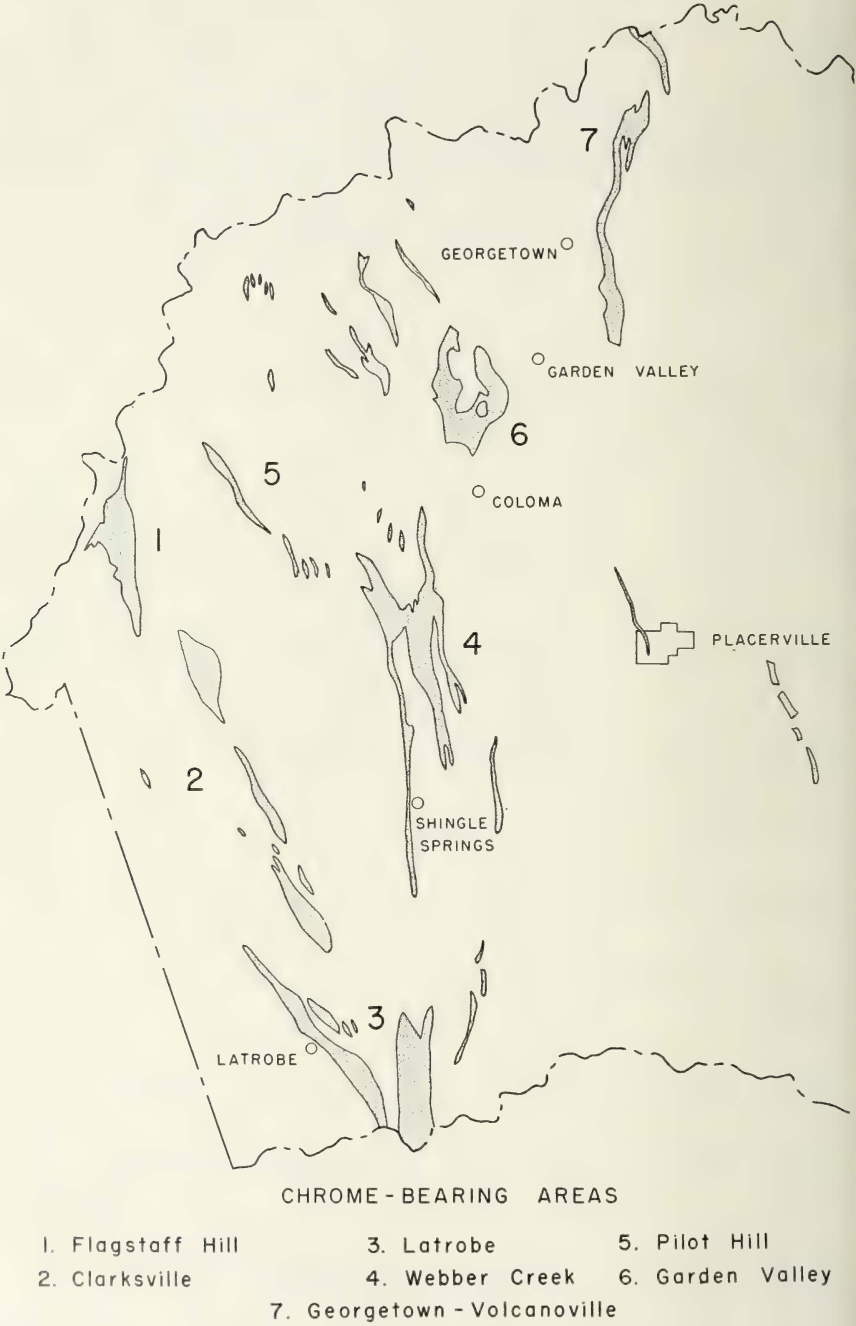

7
GEORGETOWN
GARDEN VALLEY
6
5
COLOMA
1
4
PLACERVILLE
2
SHINGLE SPRINGS
3
LATROBE
CHROME-BEARING AREAS
1. Flagstaff Hill
2. Clarksville
3. Latrobe
4. Webber Creek
5. Pilot Hill
6. Garden Valley
7. Georgetown - Volcanoville

FIGURE 5. Map of western El Dorado County showing the distribution of serpentine and chrome-bearing areas. (After Cater and others, 1951.)

and Georgetown-Volcanoville areas. During World War II, chromite deposits of El Dorado County were studied in detail by the U. S. Geological Survey (Cater and others, 1951).

Chromite is deposited as magmatic segregations in ultrabasic igneous rocks such as pyroxenite, peridotite, and dunite or in serpentine derived from these rocks. The ore bodies are kidney-shaped masses, pods, elongate lenses, or "leopard" ore (disseminated masses composed of closely spaced spheroids and ellipsoids).

Chaix Mine. Location: sec. 14, T. 8 N., R. 9 E., M. D., 2 miles southeast of Latrobe. Ownership: R. H. Chaix, Box 87, Placerville.

The Chaix chrome mine was worked on a small scale during World War I (Bradley and others, 1918, p. 132) and in 1943 (Cater and others, 1951, p. 124). During the first half of 1953, chrome ore was produced by David Chalmers and Thomas Davidson who sub-leased the property from El Dorado Chrome Company. The mine, which has yielded several hundred tons of chrome ore, has been idle since the summer of 1953.

The deposit consists of disseminated and massive chromite in serpentinized dunite (Cater and others, 1951, p. 124). The chromite bodies, which are discontinuous, commonly pinch and swell, and average 1½ feet in thickness. They occur in a zone that strikes N. 20° E. and dips 70° SE.

During 1953 disseminated ore was mined by bulldozers from an open pit, 300 feet long by 200 feet wide and about 30 feet deep. The Cr_2O_3 content of the ore was about 20 percent (David Chalmers, personal communication, 1953). The ore was trucked 16 miles to El Dorado Chrome Company's custom mill at the Church mine. Mill concentrates were trucked to the Government stockpile at Grants Pass, Oregon.

Darrington (Gurney) Mine. Location: sec. 33, T. 11 N., R. 8 E., M. D., 7 miles southwest of Pilot Hill. Ownership: George Darrington, Folsom.

The Darrington chrome mine was worked originally during World War I, and several hundred tons of ore were produced (Cater and others, 1951, p. 150). During World War II, the property was operated by J. J. Taylor in conjunction with the nearby Dobbas mine. The yield was 495 long tons of ore, most of which was from the Darrington property (Cater and others, 1951, p. 150).

The chromite is in two zones, each in separate masses of dunite. The zones contain disseminated chromite. Some pods and lenses of chromite also are present. The east ore zone is about 300 feet long and 70 feet wide. Typical analyses of ore from the zone are 11.34, 13.76, and 16.65 percent Cr_2O_3 (Cater and others, 1951, p. 151). According to Cater and others (1951, p. 151), the reserves of the milling-grade ore in the east zone may be about 100,000 tons. Some diamond drilling was done in 1943. The west zone is poorly exposed, and only small amounts of work have been done. The iron content of both zones seems to be somewhat high.

The deposits have been developed by open cuts, four adits totaling 900 feet, and shafts and raises totaling 120 feet.

Dobbas Mine. Location: sec. 22, T. 11 N., R. 8 E., M. D., 2 miles due north of Flagstaff Hill. Ownership: D. J. Dobbas, Auburn.

There was a considerable amount of activity on this property during World War I, and a number of open pits and several shafts and adits were developed (Cater and others, 1951, p. 146). During this time, the property was leased or owned by the Placer Chrome Company which sub-leased part of its holdings to the Union Chrome Company. In 1941, the Rustless Mining Corporation prospected the property. Some ore was produced which was concentrated along with ore from several other deposits in the Volo mill near Placerville. In 1942 and again in 1944, some ore was produced from the property (Cater and others, 1951, p. 146).

The deposit consists of a number of scattered ore bodies lying near the eastern margin of a mass of ultrabasic rock that has been altered largely to the talc-chlorite or talc-serpentine rock. The ore bodies strike north to northwest; some of them contain layers of disseminated chromite 1 or more feet in width. A number of assays show the ore to be high in iron (Cater and others, 1951, p. 148). There are five principal ore-bearing areas (Cater and others, 1951, pp. 144, 145). The deposits are developed by open pits and shallow shafts.

El Dorado Chrome Company. During the spring and early summer of 1953, El Dorado Chrome Company operated a custom chrome mill at the site of the Church gold mine in sec. 12, T. 9 N., R. 10 E., M. D., 6 miles south of Placerville. The 20-stamp mill, which was used formerly to treat gold ore, was renovated by the company to beneficiate chrome ore.

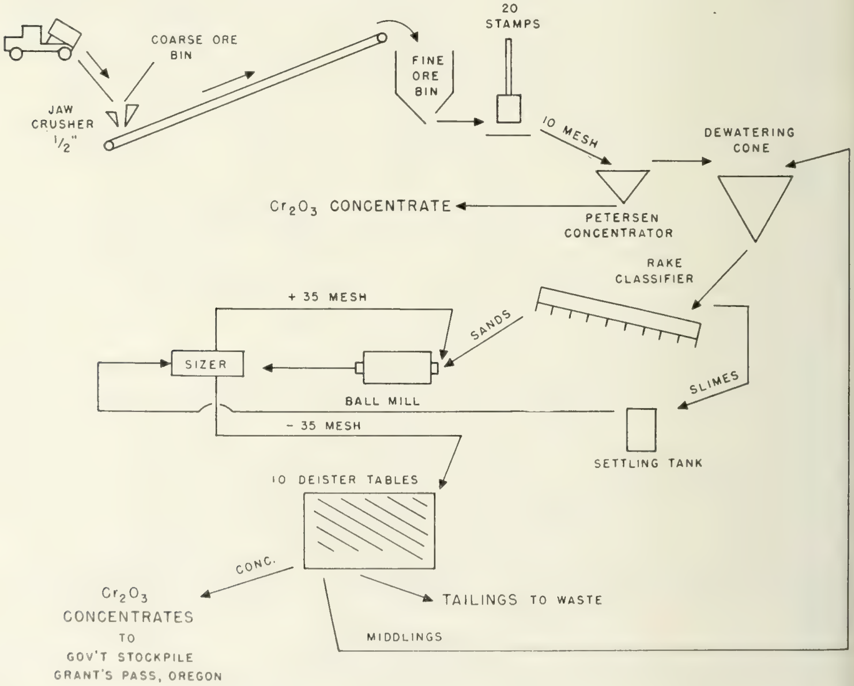

COARSE ORE BIN
JAW CRUSHER ½"
FINE ORE BIN
20 STAMPS
10 MESH
DEWATERING CONE
Cr_2O_3 CONCENTRATE
PETERSEN CONCENTRATOR
RAKE CLASSIFIER
+ 35 MESH
SANDS
SIZER
BALL MILL
SLIMES
- 35 MESH
SETTLING TANK
10 DEISTER TABLES
CONC.
Cr_2O_3 CONCENTRATES TO GOV'T STOCKPILE GRANT'S PASS, OREGON
TAILINGS TO WASTE
MIDDLINGS

FIGURE 6. Flowsheet, El Dorado Chrome Company chrome mill, Church mine, March 1953.

This concern leased a number of chromite properties in the Latrobe area, sub-leased them to different operators, and then purchased the ore produced. An approximate base price of 60 cents for each percent of Cr_2O_3 in the ore was paid to the producers. This price varied with each producer, depending on proximity of the mine and mill, and other economic factors. In some cases, the company provided trucks to haul the ore to the mill. The Murphy and Chaix mines supplied most of the ore.

At the mill, the company attempted to maintain an average mill-head grade of 20 percent Cr_2O_3. Mill capacity was 200 tons of ore per day, and mill recovery was about 75 percent. The concentrates were trucked to the Government stockpile at Grants Pass, Oregon.

Joerger Mine. Location: sec. 35, T. 10 N., R. 8 E., M. D., 8 miles west of Shingle Springs. Ownership: Bertha J. Burton, 1115 Yale, Fresno.

Some work was done in this chrome mine during World War I (Cater and others, 1951, p. 126). However, most of the ore from this property was mined in 1942. The exact tonnage is not known as it was included in the combined tonnage from several other mines.

The deposit consists of disseminated chromite found in alternating rich and lean layers. Five zones have been found in serpentine which has intruded metalvolcanic rocks of the Amador group. The zones trend N. 25°-60° E., dip steeply northwest or southeast, and range from 6 to 30 feet in width. A diorite dike has cut off the zones to the east. Estimated ore reserves are 10,000 to 15,000 tons containing 5 to 8 percent Cr_2O_3 (Cater and others, 1951, p. 126). The ore milled in 1942 averaged 8 percent Cr_2O_3. The deposit was worked in an open pit 150 feet long, 15 to 40 feet wide, and 25 feet deep.

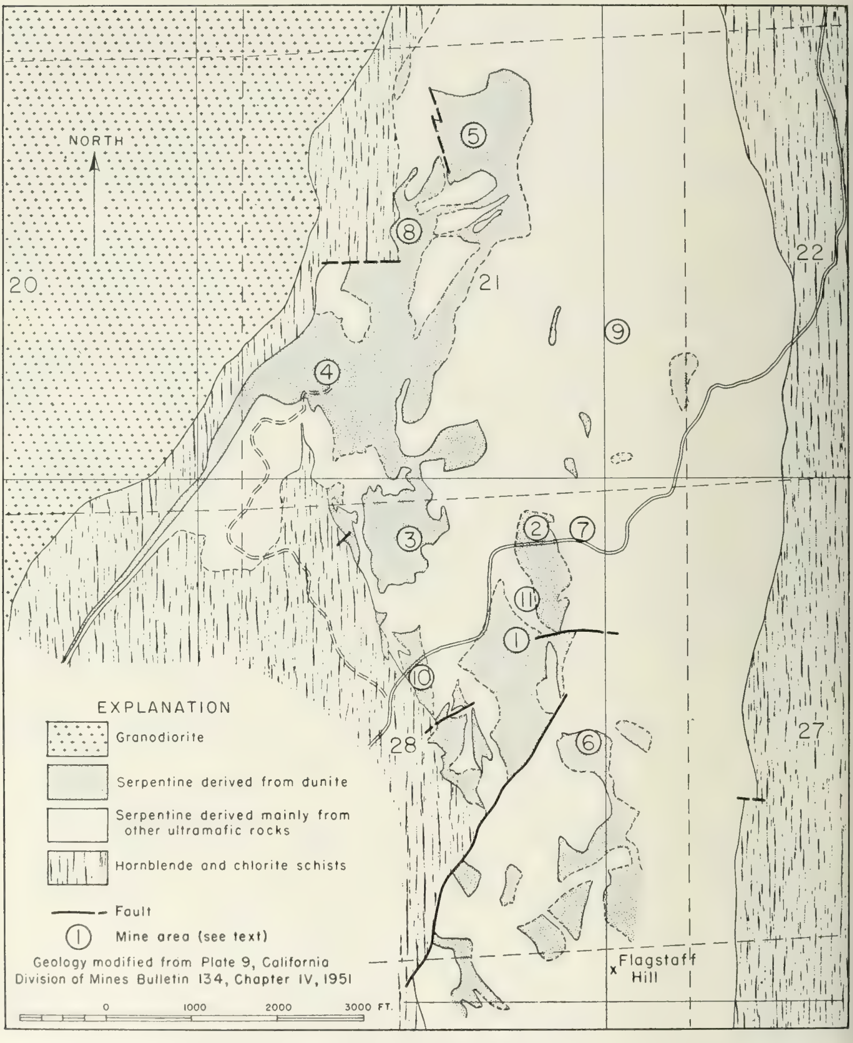
Murphy Mine. Location: sec. 14, T. 8 N., R. 9 E., M. D., 2 miles southeast of Latrobe. Ownership: W. C. Egloff, Box 506, Folsom.

The Murphy chrome mine was worked during World War I when about 3000 tons of ore from the property was milled. In 1942 it was worked by the Yolo Mining Company when 2000 tons of ore were produced. During the first half of 1953 the mine was operated by Edward Hadsel and Jerry Grant, who sub-leased the property from El Dorado Chrome Company. For a few months in 1953, about 100 tons of ore per day were produced. The mine has been idle since.

The deposit consists of lenses of disseminated chromite in serpentized dunite. The lenses have a general strike of N. 20° E. and dip steeply west. The tenor of the ore mined in 1953 was 14 percent Cr_2O_3 with a 2.7 to 1 chrome-iron ratio (Jerry Grant, personal communication, 1953).

The property is developed by two open pits. The larger pit is 200 feet long and 10 to 30 feet wide with a 25-foot face at the north end. Jackhammers were used for drilling. The ore was trucked 16 miles to El Dorado Chrome Company mill. Eight men were employed at the mine in 1953.

Pillikin (Pilliken) Mine. Location: secs. 21 and 28, T. 11 N., R. 8 E., M. D., in the central part of the Flagstaff Hill chrome area, 6 miles southwest of the town of Pilot Hill and 8 miles due south of


NORTH
20
21
22
27
28
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
Flagstaff Hill
EXPLANATION
Granodiorite
Serpentine derived from dunite
Serpentine derived mainly from other ultramafic rocks
Hornblende and chlorite schists
Fault
① Mine area (see text)
0
1000
2000
3000 FT.

Geology modified from Plate 9, California Division of Mines Bulletin 134, Chapter IV, 1951

FIGURE 7. Geologic map showing location of chromite mines, Flagstaff Hill area.

Auburn. Ownership: American Trust Company, 464 California Street, San Francisco.

The Pillikin mine consists of a number of chromite-bearing deposits just north of Flagstaff Hill peak in the extreme western portion of the county. These deposits crop out over an area more than 2 square miles in extent. The mine contains the largest known chromite deposits in the Sierra Nevada and has been the source of more than three-quarters of the total amount of chromite produced in the county (Cater and others, 1951, p. 128).

Chromite was known to exist in this area as early as 1853 (Hanks, 1884, p. 136), and a few pockets had been worked prior to 1894 (Lindgren, 1894, p. 4). During World War I, the property was leased by the Noble Electric Steel Company and considerable chromite was pro-

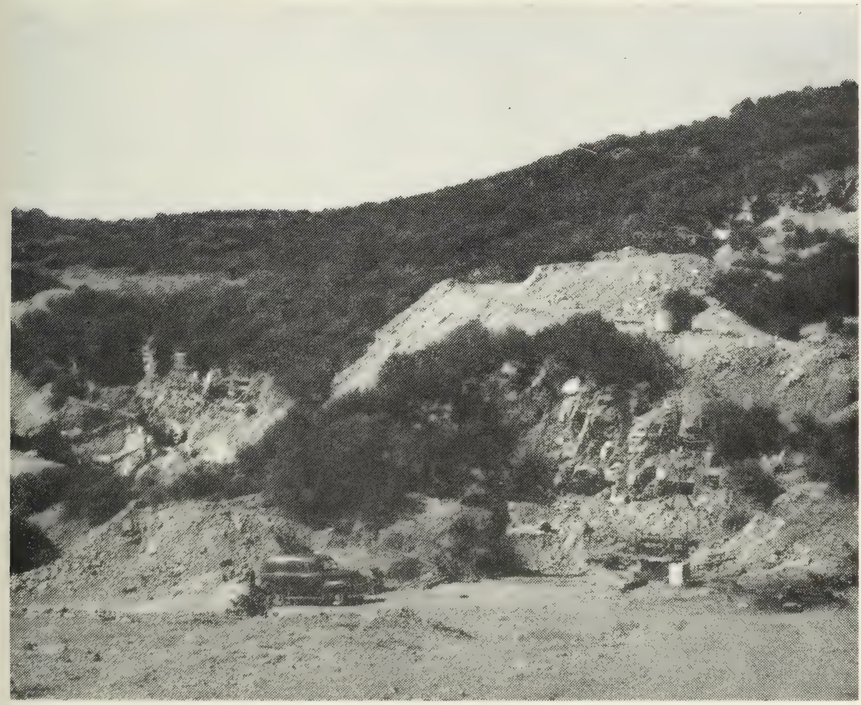


FIGURE 8. Pillikin chrome mine, West Basin Area. Camera facing north.

duced. Most of this output was in lump form that was shipped by rail from Folsom, although a small mill was erected in 1918 and some concentrate made (Cater and others, 1951, p. 131). Also some work was done during World War I by the Placer Chrome Company and the Steele Chrome Company.

The property was idle from 1918 until 1936 when it was acquired by U. S. Chrome Mines, Inc. (Cater and others, 1951, p. 131). This concern erected a 200-ton mill and operated the property until 1939. From 1940 to 1942, the mine was leased and operated by the Rustless Mining Corporation. The property was acquired by the Pillikin Syndicate in 1944. In 1945, J. J. Taylor mined a small amount of ore. Up to 1945, the Pillikin deposits had yielded a total of 27,144 long tons of chromite (Cater and others, 1951, p. 132).

In 1939, the deposit was studied by the U. S. Geological Survey. The result of this work was published in U. S. Geological Survey Bulletin 922-O, in 1940. More detailed studies and a detailed geologic map were made by the U. S. Geological Survey during 1942-43. The results of this later work were published in California Division of Mines Bulletin 134, part III, chapter 4, October 1951.

From 1951 to 1953, the property was leased by the Allied Mining Company, and a new mill was erected. However, little ore was produced and treated, and the mill was dismantled late in 1953. During 1954-55, the mine was leased by the Pillikin Mining Company, Ray Graetz, manager, and some ore was mined from Area 3, West Basin. The ore was treated at the mill at the Pioneer-Lilyama copper mine, 3 miles east of

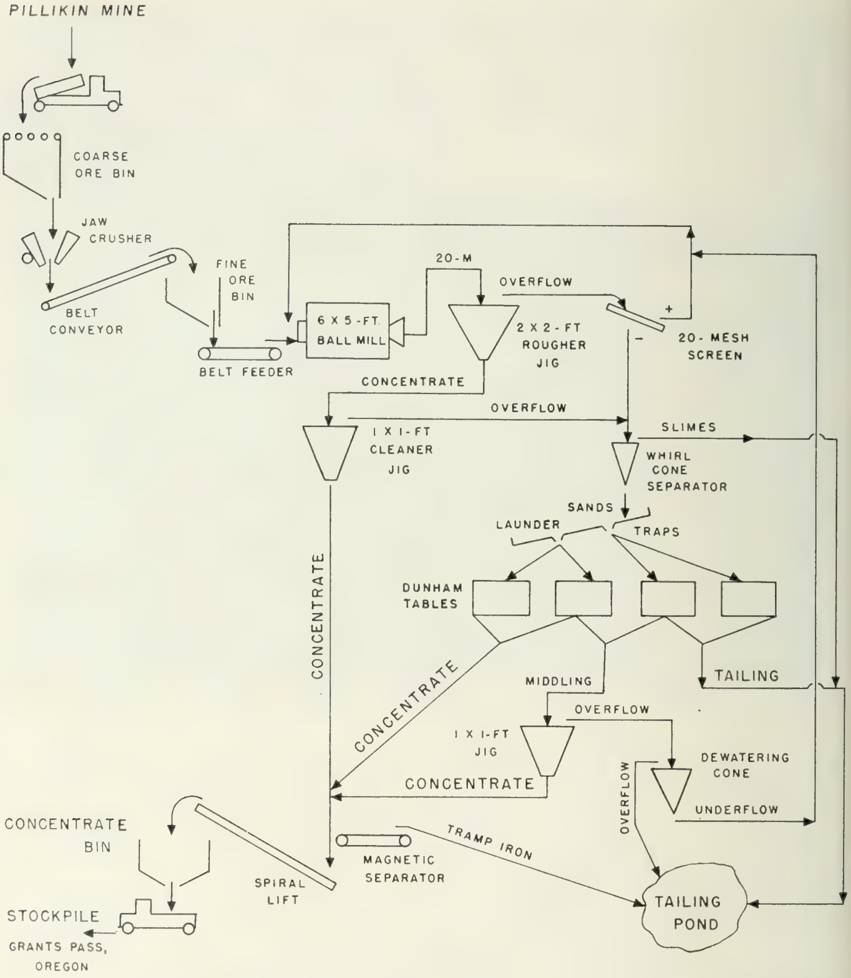

PILLIKIN MINE
COARSE ORE BIN
JAW CRUSHER
BELT CONVEYOR
FINE ORE BIN
BELT FEEDER
6 X 5 -FT. BALL MILL
20-M
OVERFLOW
2 X 2 - FT ROUGHER JIG
+
-
20- MESH SCREEN
CONCENTRATE
OVERFLOW
1 X 1-FT CLEANER JIG
SLIMES
WHIRL CONE SEPARATOR
SANDS
LAUNDER
TRAPS
DUNHAM TABLES
CONCENTRATE
CONCENTRATE
MIDDLING
TAILING
OVERFLOW
1 X 1-FT JIG
DEWATERING CONE
CONCENTRATE
OVERFLOW
UNDERFLOW
CONCENTRATE BIN
SPIRAL LIFT
MAGNETIC SEPARATOR
TRAMP IRON
TAILING POND
STOCKPILE
GRANTS PASS, OREGON

FIGURE 9. Flowsheet of Pillikin Mining Company chrome mill at Pioneer-Lilyama mine, 1955.

the town of Pilot Hill, which had been altered to handle chrome ore. The mine has been idle since April 1955.

The Pillikin chrome deposits are in a mass of ultrabasic rock about three-quarters of a mile wide and 4 miles long. The mass trends north-northwest and dips steeply east. The ultrabasic rocks have been highly serpentinized and otherwise altered. However, four varieties of the original rock have been recognized and mapped: dunite, lherzolite, pyroxenite, and layered olivine and pyroxene rock (Cater and others, 1951, p. 132). Dunite is the most common rock of the mass, while lherzolite is abundant to the east. These rocks are cut by several systems of diorite dikes.

There has been widespread hydrothermal alteration of the ultrabasic rocks which is of economic importance. Four types of alteration are recognized: serpentinization, silicification, formation of talc, and formation of magnesite (Cater and others, 1951, p. 133). Silicification produced rocks ranging from slightly silicified dunite to deep-red jasper.

Chromite is distributed throughout the dunite in concentrations ranging from less than half to more than 30 percent Cr_2O_3. Most of the deposits that have been worked are zones in which the ore consists of alternating chromite-rich and chromite-poor bands. There are a few zones containing evenly distributed disseminated chromite. The lenses and bands of pure chromite range from less than an inch to as much as 4 feet in thickness. The ore zones generally parallel the trend of the ultrabasic rock. The chromite concentrations vary greatly in size ranging from those containing a few pounds to masses containing 300,000 tons (Cater and others, 1951, p. 135). The chromites in the various ore bodies have only small variations in composition (Cater and others, 1951, p. 135). Up to 1945, shipping grade ores averaged 43 percent Cr_2O_3, while concentrates contained 43 percent Cr_2O_3 with a chromium-iron ratio ranging from 1.3 to 2.3.

Because of the irregular shape and erratic distribution of the ore bodies, the potential reserves of the deposit are unknown. Also, the geologic controls of the ore bodies are unknown as yet. It has been estimated that there are at least 450,000 tons of material containing 5 percent or more of Cr_2O_3 at depths permitting open-pit operations (Cater and others, 1951, p. 137).

There are 11 separate chromite-bearing areas in this deposit.

In Area 1 (East Basin), irregular lenses of nearly pure chromite and disseminated chromite are found in light-colored serpentine with talc and small amounts of magnesite. The ore zones trend N. 10° W. and dip 60° E. The area is underlain by dunite with pyroxenite to the east and west. During World War I, the Rustless Mining Corporation produced 37,110 tons of ore averaging 11 percent Cr_2O_3 (Cater and others, 1951, p. 138). In 1952, the open pit was dewatered by the Allied Mining Company and some shipping-grade ore was produced from a lens several feet wide at the base of the pit. The open pit measures about 400 by 400 feet and is about 75 feet deep.

The Area 2 (Bonanza King Mine) portion of the deposit first was worked during World War I by the Noble Electric Steel Company, which shipped 2,500 tons of 46 to 47 percent ore (Cater and others, 1951, p. 138). The mine also was worked by the U. S. Chrome Mines, Inc., which shipped 217 long tons of 43 percent Cr_2O_3 ore, and the Rustless Mining Company, which produced 16,130 tons averaging 9 percent Cr_2O_3 ore. The Allied Mining Company produced some ore from underground workings in this area in 1952. The ore consists of stringers of disseminated and nearly massive chromite. One large lens of ore mined during World War I was 90 feet long and 1 to 12 feet wide. It is developed by two large open pits and some underground workings that are north of the pits.

The Area 3 (West Basin) portion of the deposit was worked extensively during World War I and again during World War II. The Rustless Mining Corporation produced 5,937 tons of ore during 1941-42. In 1952, the Allied Mining Company reopened some of the old underground workings, although there was little ore production.

The last activity at the Pillikin mine—by the Pillikin Mining Company in 1954-55—was in the north portion of this area of the deposit. Two northwest-striking lenses of chromite several feet in width were worked through a 100-foot shaft. Some shipping-grade ore was produced, which averaged 47 percent Cr_2O_3 with a chrome to iron ratio of 2.8 (Ray Graetz, personal communication, 1954). The milling-grade ore, which averaged about 20 percent Cr_2O_3, was milled at the Pioneer-Lilyama mill.

Fine-grained green dunite is the predominant rock type in this area with smaller amounts of pyroxenite and lherzolite. All of the fine-grained green rock may not be dunite, however, as thin-sections made of several specimens taken from this portion of the deposit were found to be fine-grained tactite composed chiefly of epidote. Also garnierite, a nickel-bearing mineral, has been found in some of the laterite soils in this portion of the deposit that have resulted from weathering of the serpentine. As yet, the extent and amount of garnierite present is unknown.

The Area 4 (Chrome Gulch) portion of the deposit was prospected by U. S. Chrome Mines, Inc. in 1942 (Cater and others, 1951, p. 141). A number of large and small chromite bodies occur in partly serpentinized dunite. The chromite is layered; the layers trend north and dip both east and west. There are two major ore bodies that average 5 percent Cr_2O_3. These have been mapped in detail and are shown on plate 11, Bulletin 134, Part III, Chapter 4. The east ore body is estimated to contain at least 250,000 tons of ore and the west ore body 45,000 tons of ore (Cater and others, 1951, p. 142).

During the period 1917-20, *Area 5*, held by the Placer Chrome Company, shipped 7,270 long tons of lump ore and concentrates (Cater and others, 1951, p. 141). Lenses and pods of massive chromite occur in dunite that is interfingered with schist. A north-trending chromite-bearing zone about 1000 feet long is developed by glory holes, shafts, and open pits.

Area 6 was prospected during World War I by the Steele Chrome Company and again around 1940, but little or no ore was produced. Bodies of disseminated ore with a few high-grade streaks occur in a mass of dunite. Exposures indicate at least 10,000 tons of ore containing 5 percent or more of Cr_2O_3 (Cater and others, 1951, p. 143). The deposit is developed by open cuts and short adits.

Small amounts of ore were produced from *Area 7* during World War II. There is an estimated total of 25,000 tons of disseminated ore in a talcose dunite body 200 feet wide and at least 1,500 feet long (Cater and others, 1951, p. 143). It is developed by open pits and trenches.

The deposit in *Area 8* consists of dunite containing high-grade layers of chromite as much as 24 inches thick. The enclosing dunite contains some disseminated chromite. It is developed by several open pits and short adits.

During World War I, *Area 9 (Nillson or Donnelly mine)* shipped 224 long tons of ore (Cater and others, 1951, p. 143). The area was prospected again around World War II. Irregular lenses of chromite up to 18 inches in thickness occur in dunite that is almost completely altered to talc. Disseminated ore is also present.

In *Area 10* disseminated ore containing a few high-grade streaks occurs in a northwest-trending mass of dunite. Although some good ore is present, the average grade apparently is too low and the ore bodies too small for profitable mining (Cater and others, 1951, p. 146).

In *Area 11* several lenses of high-grade chromite as much as 3 feet thick were mined from shallow pits, inclined shafts, and adits. There is a high degree of shearing and much silification.

Pillikin Mining Company Mill. Location: sec. 3, T. 11 N., R. 9 E., M. D., at the Pioneer-Lilyama copper mine. Ownership: H. H. Mitchel, 9490 Brighton Way, Beverly Hills.

From November 1954 to April 1955, the Pioneer-Lilyama was leased by the Pillikin Mining Company. Chrome ore from the Pillikin mine was concentrated and the concentrates trucked to the Government stockpile at Grants Pass, Oregon. Ore was trucked to the mill from the Pillikin mine, 8 miles to the southwest, and treated by crushing, fine grinding, jigging, and tabling.

Some of the milling equipment that was used previously in the treatment of copper ore from the Pioneer-Lilyama mine was utilized. The ball-mill product was 20 mesh. Water from milling was obtained from the adit of the copper mine. Fifty tons of ore per day were treated. Three tons of ore yielded an average of about 1600 pounds of concentrates (Gratz, R., personal communication, 1955). Mill heads averaged 27 percent Cr_2O_3. Two shifts of four men each worked at the mill.

Walker Mine. Location: sec. 35, T. 10 N., R. 8 E., M. D., 8 miles west of Shingle Springs. Ownership: Faustino Silva, Route 8, Box 951, Sacramento.

Some chrome ore was produced from this property in 1917 and again in 1918. In 1942 the property was worked by the Yolo Mining Company of Placerville (Cater and others, 1951, pp. 126, 128).

The deposits consist of disseminated chromite in alternating rich and lean layers in serpentine which was intruded into metavolcanic rocks of the Amador group. The ore zone strikes N. 35° W., dips steeply northeast, and is 3 to 4 feet wide. Estimated ore reserves to the depth of the shaft are 1500 tons containing 10 to 12 percent Cr_2O_3. The property is developed by a 60-foot shaft with 30 feet of drifts on the 60-foot level and numerous open cuts.

Copper

Recorded output of copper in El Dorado County since 1880 is 834,562 pounds, valued at $155,151. However, copper was produced in the county prior to that date. In 1859, copper ore was being mined at the Cosumnes mine, and it was known to occur in several other localities in the county (Aubury, 1908, p. 31). During the Civil War days of the early 1860's, substantial quantities of copper ore were produced in the Sierran foothills and shipped to smelters in Boston, Baltimore, and Wales. During World War I, copper was produced at several properties. Since 1927, some copper ore has been produced in the county nearly every year. At the present time there is some production from the El Dorado, Noonday, Pioneer-Lilyama, and Cosumnes mines. Also, copper ore from the Copper Hill mine in Amador County is concentrated in the Volo mill. Small amounts are recovered as by-products of gold mining.

Along the western Sierran foothills and west of the Mother Lode is a belt of copper and zinc mineralization. This belt contains lenticular sulfide bodies that were formed by cavity filling and replacement along zones of shearing, faulting, and crushing in metamorphic rocks of Paleozoic and Jurassic age. The ore bodies are composed chiefly of pyrite with varying amounts of pyrrhotite and chalcopyrite. Sphalerite, bornite, chalcocite, galena, tetrahedrite, gold, and silver are present in smaller amounts. The ore deposition is controlled by the structure, and the copper mineralization is genetically related to the emplacement of the Sierra Nevada granitic batholith.

Copper in El Dorado County also occurs in contact metamorphic rocks where granitic rocks have intruded calcareous metamorphic rocks. Chalcopyrite with appreciable amounts of bornite are the principal ore minerals in these deposits. Copper ore is found in the Mother Lode belt at the El Dorado copper mine at Garden Valley. Copper also occurs as a minor constituent of lode gold ores.

Big Buzzard (Hercules, Darrington) Mine. Location: sec. 29, T. 11 N., R. 8 E., M. D., 3 miles southwest of Rattlesnake Bridge and half a mile east of the American River. Ownership: George Darrington et al., Folsom.

The Big Buzzard copper and zinc mine originally was worked as a gold mine, and the ore was treated in a five-stamp mill (Logan, 1923, p. 142). During the period 1900-10, the mine was leased by several concerns; however, there was little production. In 1926 there was some additional underground development (Logan, 1926, p. 406). During 1943 and 1944, several lessees shipped some copper-zinc ore from the dump. In 1948, the Morning Star Mining Corporation leased the mine and made a test run of some dump material at the Pioneer-Lilyama mill.

The deposit occurs in amphibolite and mica schist near granodiorite which lies to the west. The vein strikes northwest and dips northeast. It is as much as 10 feet wide. The ore is complex and contains appreciable quantities of sphalerite with pyrite, chalcopyrite, and galena. Some of the ore contained as much as $14 per ton in gold (Logan, 1926, p. 406). The ore shoot pitches south. There is a 300-foot inclined shaft sunk on the vein with levels at 70, 160, 260, and 300 feet. Most of the stoping has been on the 70 and 160-foot levels.

Cosumnes Mine. Location: secs. 24, 25, T. 9 N., R. 12 E., M. D., 4 miles northwest of Fairplay, by the Cosumnes River. Ownership: Clifford Smith, Somerset, leased by Lee Miller, Fairplay.

The Cosumnes copper mine was worked originally in 1859 (Aubury, 1908, p. 31). It was active again around 1896 and during World War I. During World War II, a small amount of ore was produced from open cuts on the hill above the adit portal and treated at the Volo mill near Placerville (Lee Miller, personal communication, 1955). The present operator, who leased the property early in 1955, has reopened some of the old workings and produced several tons of ore that have been stockpiled.

Copper minerals occur in a contact metamorphic zone that lies between limestone on the east and granodiorite on the west. The principal gangue is tactite composed of garnet and epidote with some calcite and quartz. The ore minerals are bornite and chalcopyrite. Pyrite, molybdenite, magnetite, and powellite are present in smaller amounts. Minor amounts of gold and silver are present. The tactite bodies trend northeast and are as much as 30 feet wide. Other rocks in the immediate area are amphibolite and mica schist. Some of the tactite is slightly radioactive (Lee Miller, personal communication, 1955).

The mine is worked through a 150-foot crosscut adit driven westward with drifts running northeast and southwest along the mineralized zone. A 30-foot raise is being driven just south of the adit-drift intersection. Also, there is a lower crosscut adit about 40 feet below the main adit. These two levels are connected by a winze. There are a number of caved workings the extent of which are unknown. There are numerous open cuts on the hill above the adit portals. Three men including Mr. Miller work at the mine.

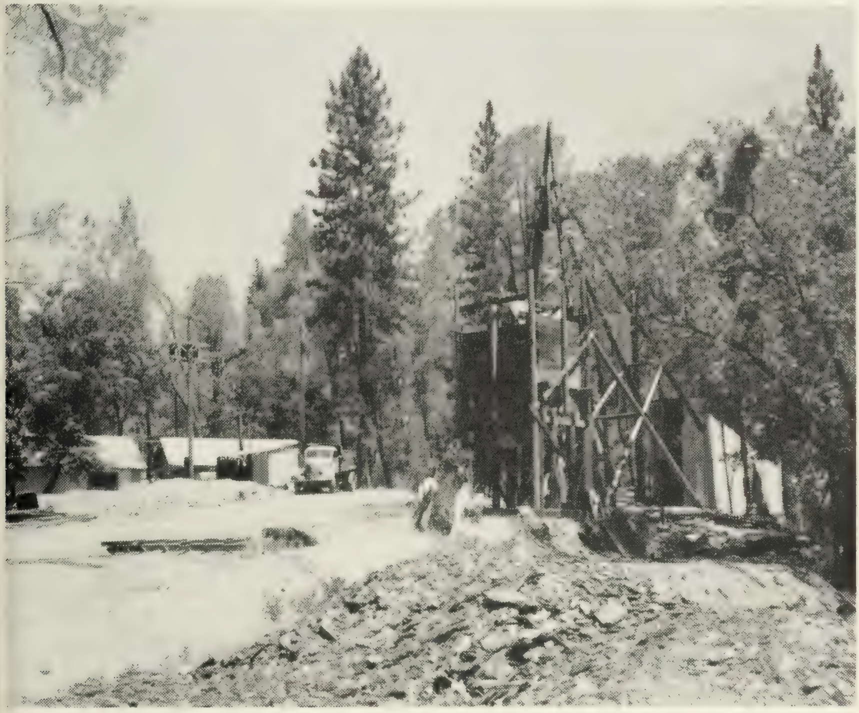


FIGURE 10. El Dorado copper mine.

El Dorado (Roosevelt) Mine. Location: sec. 34, T. 12 N., R. 10 E., M. D., 1 mile southeast of Garden Valley. Ownership: Calivada Development Company, Box 4, Garden Valley.

Since 1953, there has been intermittent development work and some ore production from El Dorado copper mine. The shaft was deepened to 100 feet and about 50 feet of drifts were driven on the new 100-foot level. New surface equipment, including a headframe, buildings, and a compressor, were installed. This work is being done by the Calivada Development Company, H. T. Hall, president.

This mine originally was worked for gold in the 1860's when a north-trending adit was driven. During World War II, some copper ore was mined. In 1944-45, the U. S. Bureau of Mines made an examination of the property, the results of which were published in the U. S. Bureau of Mines Report of Investigations 3896, June 1946 (Bedford, 1946). Exploration was done by means of diamond drilling and sampling of exposures.

El Dorado copper deposit is in the Mother Lode gold belt. Country rock is black Mariposa slate. Small amounts of fine-grained green tuffaceous rock are interbedded with the slate. The ore, which is indicated on the surface by narrow zones of gossan, is composed of massive chalcopyrite, pyrrhotite, and pyrite. The massive sulfides occur in bands up to several feet in thickness and evidently have replaced the green tuffaceous rock. There is also disseminated chalcopyrite in the wall rock of the deposit. On the 100-foot level there are five parallel bands of ore in a zone about 5 feet wide. Strike is to the northwest; dip is to the northeast or vertical.

Exploration work done by the U. S. Bureau of Mines consisted of eleven diamond drill holes aggregating a total of 1,613 feet. Eight of the holes drilled indicated the deposit to be essentially a series of narrow intermittent lenses of ore along structures about 600 feet in length (Bedford, 1946, p. 1) and extending several hundred feet in depth. Apparently the greatest amount of ore is in the vicinity of the shaft. Copper content of the ore ranges from 5 to a little more than 10 percent. As much as 1.5 percent zinc, about 1 ounce per ton in silver, and traces of nickel and gold also are present in the ore.

The mine is developed by a two-compartment 100-foot shaft inclined to the east. A north-trending 173-foot adit, driven as a crosscut for 46 feet and as a drift for 127 feet, connects with the shaft on the 50-foot level 128 feet in from the adit portal. On the 100-foot level there are drifts extending 35 feet to the north and 10 feet to the south.

Noonday Mine. Location: sec. 18, T. 9 N., R. 11 E., M. D., 4 miles southeast of El Dorado and half a mile east of the Mother Lode. Ownership: George Fausel, Placerville, leased by the Noonday Copper Mining Co., R. F. Fitzgerald, president.

The Noonday copper mine was active during the period 1900-05 when it was developed by shallow workings (Eric, 1948, p. 231). A shaft later was extended to a depth of 200 feet, and several hundred feet of drifts were driven. Ore containing 5 to 9 percent copper and some gold and silver was mined (Tucker, 1919, p. 278).

Early in 1953, the mine was reopened by the Noonday Copper Mining Company. The shaft was rehabilitated and about 100 feet of new drifts driven. Several thousand tons of ore was mined and was milled at the Volo mill west of Placerville. It was shut down in 1954. Early in 1956 the mine was reopened, and at present small amounts of ore are being mined from the 200-foot level.

This deposit occurs in a shear zone in schist of the Calaveras group, about half a mile east of the Mother Lode gold belt. The vein strikes north to northeast and dips steeply east. It is as much as 7 feet wide. The ore consists of chalcopyrite associated with pyrite and smaller amounts of bornite. Ore mined during the last operation contained as much as 4 percent copper, although the tenor was considerably less

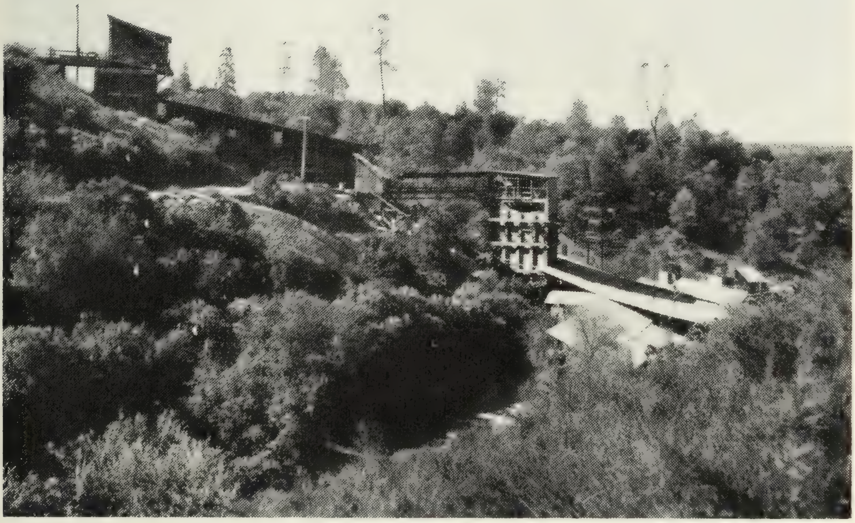


FIGURE 11. Volo mill at Shaw gold mine.

(Joseph Pickering, personal communication, 1955). Minor amounts of gold and silver were recovered. The mine is developed by a two-compartment 230-foot vertical shaft with levels at 100 and 200 feet. There are approximately 350 feet of drifts. Five men work at the mine.

Pioneer-Lilyama (Little Emma, Volo) Mine. Location: sec. 3, T. 11 N., R. 9 E., M. D., 3 miles east of Pilot Hill. Ownership: H. H. Mitchel, 9490 Brighton Way, Beverly Hills; leased by Wilcox-Lilyama Mining Company, F. R. Wicks, manager, Frank James, mine foreman, and D. W. Reynolds, mill foreman.

This property is a consolidation of the Pioneer and Lilyama copper mines, which originally were worked in the 1860's (D. W. Reynolds, personal communication, 1954). However, the main copper deposit was not discovered until 1889-90 when the adits were driven (Aubury, 1908, p. 212). The mine was idle until 1943 when it was reopened by the Volo Mining Company of Placerville (Cox and others, 1948, p. 44). A considerable amount of copper and smaller amounts of gold and silver were produced until 1948, when the mine was shut down. The ore was concentrated by flotation in a mill on the property. During 1943-44, the U. S. Geological Survey examined the ore deposit and made geologic maps of the area. The results of this work were published in California Division of Mines Bulletin 144.

During the fall of 1954 and spring of 1955 the mill was leased to the Pillikin Mining Company and used to treat chrome ore from the Pillikin mine. Since July 1955 the present operator has been rehabilitating the mine and altering the mill. Some ore has been produced and is stockpiled, awaiting completion of the work on the mill.

This deposit is near the west margin of a granodiorite stock that has intruded metasedimentary rocks of the Calaveras group. The deposit trends north and is in contact-metamorphic rocks, which include tactite and hornfels and marble. Hornfels is the most prevalent metamorphic rock type near the mine, while granodiorite is the principal intrusive rock. The tactite contains garnet, epidote, magnetite, quartz, calcite, and smaller amounts of idocrase, pyrite, chalcopyrite, bornite, ilmenite, feldspar, and specular hematite. Minor amounts of scheelite have been found (Cox and others, 1948, p. 45). The composition of the tactite varies considerably. The tactite bodies range in size from small pods to those 100 or more feet in width.

The ore bodies are those parts of the tactite that contain commercial amounts of chalcopyrite and bornite. The sulfides occur as irregular masses or veinlets and commonly are associated with abundant euhedral magnetite crystals. Small amounts of gold and silver are present in the sulfides. The mine is developed by four northeast-trending crosscut adits. An upper adit encounters ore 120 feet in from the portal, and a north-trending 150-foot drift has been driven along the ore zone. On the hill above are open cuts, trenches, and two glory holes which are connected with this level by raises. The adit has been rehabilitated, but no work is being done on this level.

On the lower or main level, there are two nearly parallel northeast-trending crosscut adits about 30 feet apart. The southern adit, which is the main haulageway, encounters the ore zone 250 feet from the portal. The ore zone was explored by a 100-foot drift to the southeast and a 120-foot drift northwest. From the end of the northwest adit, a crosscut was driven 180 feet northwest to a second ore zone that was explored by short drifts. At the intersection of the adit and drifts, a 63-foot vertical winze connects with a lower level. On this lower level, drifts extend 35 feet northwest and 75 feet southeast. Also, there are several inaccessible shafts on the property. Present work is confined to the winze and the drifts southeast of the adit. These are being rehabilitated, and any ore produced is stockpiled at the mill.

The mill is equipped with a Wheeling jaw crusher, conveyor belt, 6- by 6-foot Allis Chalmers ball mill, Wemco screw classifier, drum-type magnetic separator, 10 Denver sub-flotation cells, and two Dunham Economy tables. The capacity of the mill is being increased from 150 to 200 tons per day (D. W. Reynolds, personal communication, 1956). In 1948, the concentrate averaged 28 percent copper, 28 to 34 dollars per ton in gold, and 14 dollars per ton in silver (D. W. Reynolds, personal communication, 1956).

Rip and Tear (Dodson) Mine. Location: sec. 3, T. 8 N., R. 9 E., M. D., 2 miles north of Latrobe. Ownership: F. H. Dodson, 2404 26th Street, Sacramento.

The Rip and Tear or Dodson copper mine was worked originally during California's "copper boom" of the 1860's. In 1918, the shaft was reopened and two carloads of ore were shipped to a smelter (Logan, 1926, p. 408). In 1943, the property was leased by W. J. Varozza of Latrobe who cleaned out the underground workings and shipped a small amount of ore (F. H. Dodson, personal communication, 1954). It has been idle since.

The deposit consists of bands and stringers of massive pyrite containing appreciable amounts of chalcopyrite and pyrrhotite. These occur in a northwest-striking shear zone in fine-grained metavolcanics. The ore body averages 5 feet in width and contains as much as 10 percent copper (F. H. Dodson, personal communication, 1954). Appreciable quantities of gold and silver also are present. The mine is developed by a 100-foot main shaft and drifts. There is a 40-foot shaft on the same property about a mile to the north of the main shaft.

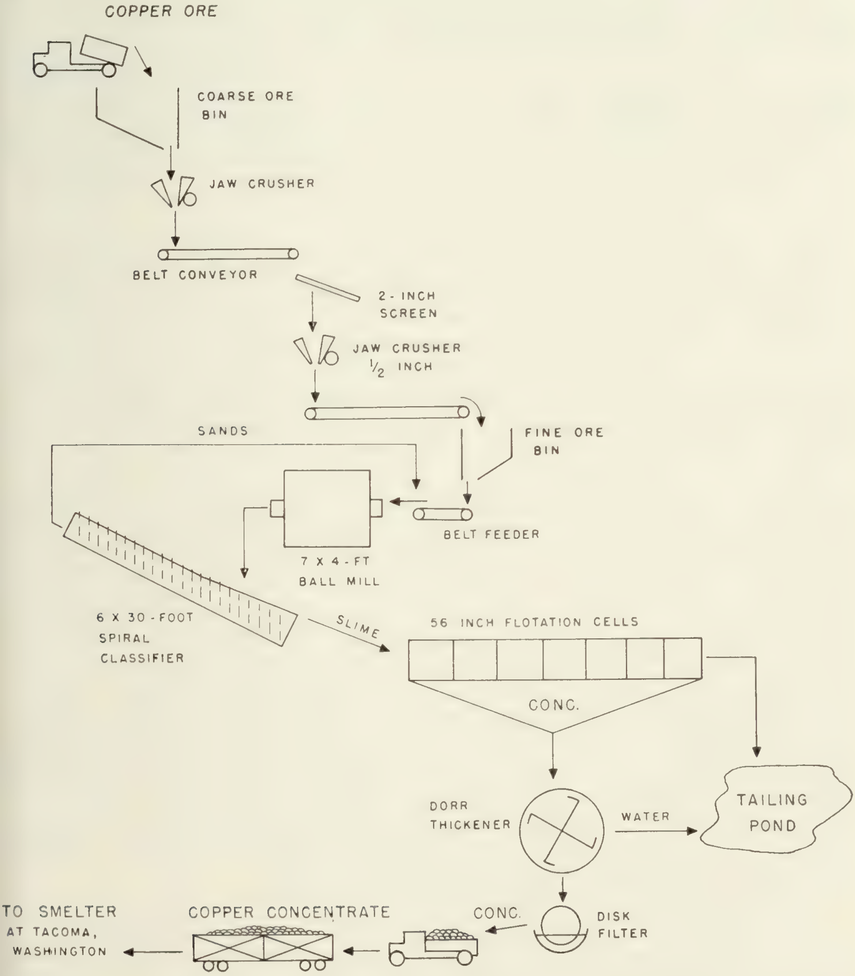

COPPER ORE
COARSE ORE BIN
JAW CRUSHER
BELT CONVEYOR
2-INCH SCREEN
JAW CRUSHER ½ INCH
SANDS
FINE ORE BIN
BELT FEEDER
7 X 4-FT BALL MILL
6 X 30-FOOT SPIRAL CLASSIFIER
SLIME
56 INCH FLOTATION CELLS
CONC.
DORR THICKENER
WATER
TAILING POND
DISK FILTER
CONC.
COPPER CONCENTRATE
TO SMELTER AT TACOMA, WASHINGTON

FIGURE 12. Flowsheet (copper circuit) at Volo mill.

Volo Mill. Location: sec. 21, T. 10 N., R. 10 E., M. D., at Shaw mine, 5 miles southwest of Placerville. Ownership: Volo Mining Company, Placerville, F. V. Phillips, president, J. Pickering, mill foreman.

During 1941-42 and again from 1946-53, gold ore from the nearby Shaw mine was treated in this mill by gravity concentration, flotation, and cyanidation. During World War II, copper ore from several properties in the county was treated in the mill by flotation. Also some chrome ore was milled during World War II. In 1953, copper ore from the Noonday mine was milled. The Shaw and Noonday mines, however, were shut down and the mill was idle until the fall of 1954, when the Copper Hill copper mine in Amador County was reopened. New equipment was installed and the flowsheet simplified. At the present time, about 50 tons of copper ore per day from the Copper Hill and Noonday mines are treated by flotation. Concentrates are shipped by railroad to the American Smelting and Refining Company's Tacoma smelter. Millheads contain 4 to 7 percent copper and 1 to 5 percent zinc (J. Pickering, personal communication, 1955). The zinc is not recovered, although there is a zinc flotation circuit at the mill. Smelter receipts show the concentrates contain 15 to 20 percent copper, 8 to 12 ounces of silver per ton, and 0.1 to 0.2 ounces of gold per ton. Four men work at the mill.

Gold

Introduction. Although the total gold output of El Dorado County is not as great as that of several other counties in California, there is probably no other area of similar size in the state where gold occurs in such a wide variety of deposits. Gold not only occurs in veins in the Mother Lode and the East and West belts, but also in contact metamorphic and replacement deposits. It is found in stream placers ranging from Tertiary to Recent in age, and in residual placers or ''seam diggings.''

History. California's gold rush began soon after James Marshall's discovery at Coloma in 1848. The rich and virgin surface placers yielded large amounts of gold during the first few years of the gold rush. After these were exhausted, hydraulic mines were a major source of gold in the county. Also ''seam diggings'' yielded substantial amounts. In 1884, hydraulic mining was severely curtailed by the Sawyer Decision, which prohibited the dumping of debris into the Sacramento and San Joaquin Rivers and their tributaries.

After the Sawyer Decision was passed, underground lode mines became the chief source of gold in the county. During the latter part of the nineteenth century, improved underground mining practices as well as new concentrating methods, such as chlorination and, later, cyanidation, were introduced which made many lode deposits workable economically. During the flush years of World War I and the 1920's, the gold output of El Dorado County was small.

During the 1930's, low costs, coupled with an increase in the gold price to $35 per ounce in 1934, caused gold production figures to rise abruptly. During these times, a large number of creeks were worked by dragline dredges or ''doodlebugs.'' The peak of this production came in 1939 when more than 2½ million dollars worth of gold was produced.

World War II with its high wages and scarcity of materials caused a great drop in gold mining in the county. In November 1942 War Production Board Order L-208 went into effect which further restricted gold mining, and nearly all of the mines closed. Only a few thousand dollars were produced in 1943-44, much of it a by-product of copper-zinc mining.

Order L-208 was lifted in July 1945, but only a few mines reopened. Since World War II, gold mining has continued to follow a diminishing trend. The discovery of the Hazel Creek mine, which now is the chief source of gold in the county, has been the only recent significant development in gold mining in El Dorado County.

Lode Deposits

Lode-gold deposits in El Dorado County are found in the Mother Lode system, the East Belt, and the West Belt. The Mother Lode belt has been the source of the largest amount of lode gold produced in the county. There also has been substantial gold production in both the East and West Belts.

The Mother Lode belt is a system or zone of steeply dipping gold-bearing quartz veins that traverses the central portion of the county. The belt trends north through Nashville, northeast through Placerville, and northwest to Garden Valley. At Garden Valley, the Mother Lode belt splits with one branch extending northwest through Greenwood to the Middle Fork of the American River, while the other extends north through Georgetown to the Georgia Slide area. This area is considered to be the north end of the Mother Lode belt (Knopf, 1929, p. 48). A number of the gold mines in the northern portion of the Mother Lode belt in El Dorado County are classed as ''seam diggings'' (see section on seam deposits).

The Mother Lode veins are enclosed in Mariposa slate with associated greenstone. The vein system or zone ranges from a few hundred feet to a mile or more in width. Within the zone are numerous discontinuous or linked veins which may be parallel, convergent at small angles, or slightly en echelon. They cut the enclosing rocks at acute angles both in strike and dip (Knopf, 1929, p. 24). Few of the veins can be traced for more than a few thousand feet along the strike. The veins commonly pinch and swell.

Mother Lode veins were formed in fissures that developed in a zone of reverse faulting. Repeated movements along the fissures facilitated the passage of mineral-bearing solutions that originated from deep-seated granitic magmas of the Sierra Nevada. The veins are composed of quartz in which disseminated gold and associated sulfides, chiefly pyrite, occur in ore shoots of varying extent. Other minerals present include ankerite, calcite, chlorite, sericite, and mariposite. The grade of Mother Lode ores is low to moderate with an average of roughly $10 per ton in gold. However, the ore shoots often are extensive and persist at depth, in some cases to several thousand feet. Bodies of auriferous greenstone and altered schist occur adjacent to Mother Lode veins as wall-rock replacements in several areas in the county.

Lying east of the Mother Lode is the area known to miners as the East Belt. It consists of many individual gold-bearing veins in metamorphic rocks of the Calaveras group or in granitic rocks. Although many of these deposits trend north, a few trend west. Most dip steeply. The ore shoots are smaller and the veins narrower than those of the Mother Lode, but commonly they are richer. The gold usually is associated with appreciable amounts of pyrite, chalcopyrite, pyrrhotite, galena, sphalerite, and arsenopyrite. The most productive areas of the

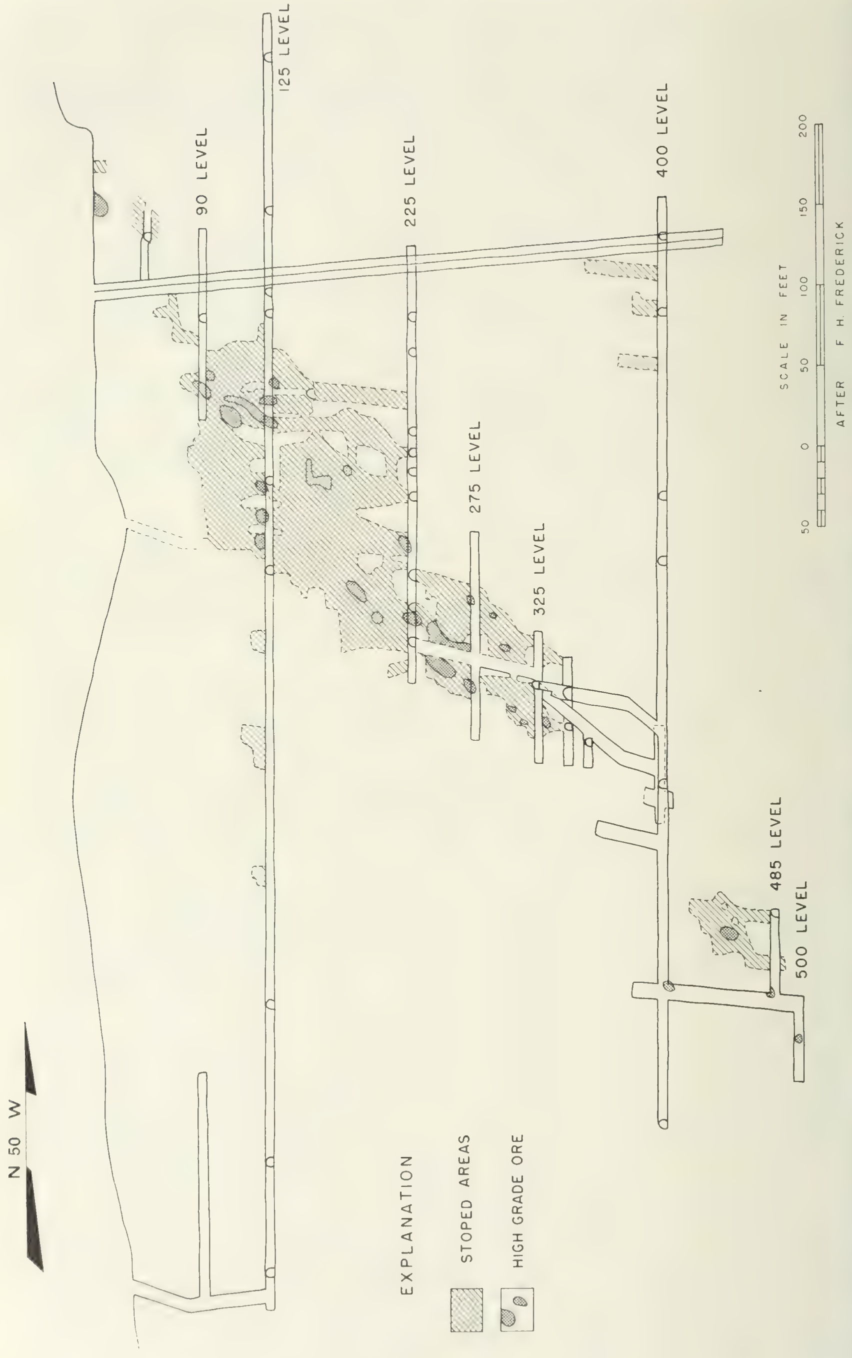

N 50 W
EXPLANATION
STOPED AREAS
HIGH GRADE ORE
90 LEVEL
125 LEVEL
225 LEVEL
275 LEVEL
325 LEVEL
400 LEVEL
485 LEVEL
500 LEVEL
SCALE IN FEET
50
0
50
100
150
200
AFTER F. H. FREDERICK

FIGURE 13. Longitudinal map of the underground workings, Alhambra gold mine, showing principal work done by the Alhambra-Shumway Mining Company.

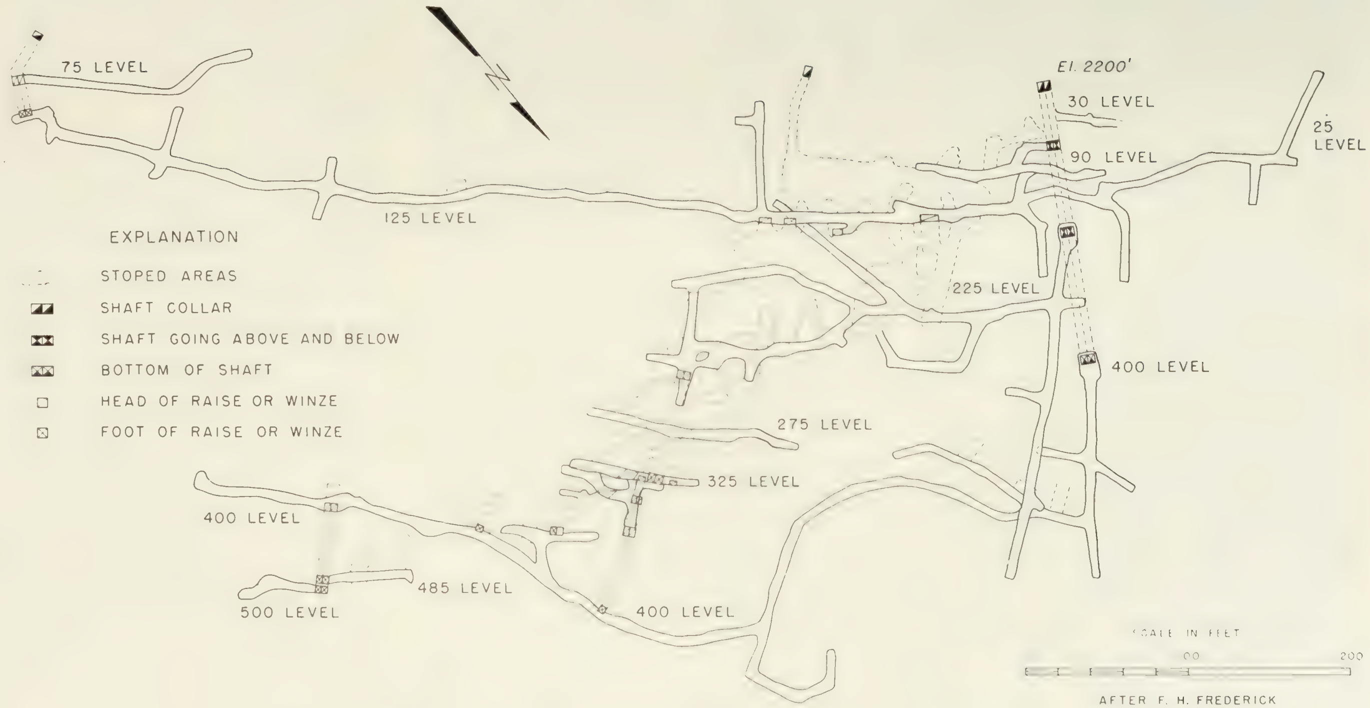

75 LEVEL
125 LEVEL
El. 2200'
30 LEVEL
90 LEVEL
25 LEVEL
225 LEVEL
400 LEVEL
275 LEVEL
325 LEVEL
400 LEVEL
485 LEVEL
500 LEVEL
400 LEVEL
EXPLANATION
STOPED AREAS
SHAFT COLLAR
SHAFT GOING ABOVE AND BELOW
BOTTOM OF SHAFT
HEAD OF RAISE OR WINZE
FOOT OF RAISE OR WINZE
SCALE IN FEET
100
200
AFTER F. H. FREDERICK

FIGURE 14. Composite map of underground workings of the Alhambra gold mine.

East Belt in El Dorado County have been the Sly Park, Grizzly Flat, and Spanish Flat areas. The Hazel Creek mine north of Grizzly Flat is the chief source of gold in the county at the present.

West of the Mother Lode in the West Belt, the gold is in quartz veins and in bodies of greenstone. The veins occupy fissures in amphibolite and chlorite schist and granodiorite. The gold is associated with pyrite and small amounts of galena. The auriferous greenstone bodies are replacement deposits in shear zones. Much of the gold in these deposits is closely associated with pyrite and in some cases with arsenopyrite. The largest production in the West Belt has been in the Deer Valley, Shingle Springs, and Frenchtown areas.

Alhambra Mine. Location: secs. 6 and 7, T. 11 N., R. 11 E., M. D., 1 mile east of Spanish Flat and 2 miles northeast of Kelsey. Ownership: Wilbur E. Timm, c/o County Courthouse, Placerville; leased by Alhambra-Shumway Mines, Inc., 681 Market Street, San Francisco, and sub-leased to Alhambra Gold Mine Corporation, 1930 Outpost Drive, Hollywood.

The Alhambra gold mine was worked originally in 1883 when a 29-foot shaft developed an ore shoot that yielded $27,600 (Logan, 1938, p. 216). It was active again in 1886, and in 1890 there was a five-stamp mill on the property (DeGroot, 1890, p. 178). The mine was idle until 1934 when it was reopened by Jensen and Schneider. These operators discovered two high-grade pockets at a depth of about 90 feet, each of which yielded more than $10,000 (Logan, 1938, p. 216).

Soon after, the Alhambra-Shumway Mining Company was formed, which leased the property. This concern since has done most of the development work and is responsible for the largest portion of the gold produced from the mine. In 1939, one of the richest pockets of high-grade ore found in California in recent years was discovered in the Alhambra mine. This pocket, in the vein between the 225- and 275-foot levels and about 250 feet southeast of the shaft, yielded about $550,000 (F. H. Frederick, personal communication, 1955). This discovery attracted much attention at the time and was featured in several newspaper articles. The mine was active until late in 1942 when it was shut down.

In 1945, the mine was leased by W. W. Williams who did some prospecting work. However, there was no reported gold production. In 1947, the mine was sub-leased by the Alhambra Gold Mine Corporation, O. H. Griggs, president. The mine was de-watered, equipment rehabilitated, and new development work done. According to O. H. Griggs, additional underground development work was done, most of it to block out ore between the 125- and 360-foot levels (this would be in addition to the work shown on the accompanying mine maps). In 1949, a high-grade pocket was discovered on the 225-foot level. A portion of this ore weighing 197 pounds yielded 324 ounces of gold (O. H. Griggs, personal communication, 1955). Soon after this discovery, the concern became involved in a lawsuit, and the mine was shut down. It is now idle, pending the outcome of the suit. The total output of the mine is approximately $1,250,000 (F. H. Frederick, personal communication, 1955). At least 50 percent of this total was from high-grade ore.

This deposit is about 2 miles east of the Mother Lode and lies near the east margin of the belt of Mariposa slate. Country rock consists of interbedded amphibolite schist, graphitic schist, and slate. The vein occurs in a fault zone and consists of strings of nodule- or pod-like bodies of quartz in chlorite-sericite schist and slaty schist. The vein has an average strike of N. 50° W. and dips northeast. There are several smaller parallel veins in the hanging wall. The main hanging wall is composed of hard amphibolite schist, while the footwall is graphite-sericite schist and slate. The main fault-zone trends northwest and dips northeast. East of the main shaft the main fault splits to the northwest; the two branches continue to strike in a general northwest direction, but 10 to 20 degrees apart. The junction has been favorable for the localization of the ore shoot and also is the channel along which the gold-bearing solutions are believed to have come (F. H. Frederick, personal communication, 1955).

Much of the gold was free and was associated with pyrite and appreciable amounts of arsenopyrite. The ore shoot was lensoid in character and plunged to the southeast. The high-grade pockets also were lensoid in character and plunged to the southeast. The famous pocket found in 1939 was nearly 5 feet wide (see California Division of Mines Bulletin 141, plate 2, view F). Associated with the quartz veins are a number of lensoid bodies of calcite and several schistose dikes.

The mine is developed by a 440-foot inclined shaft and an older 75-foot shaft about 600 feet to the southeast. There are approximately 3000 feet of drifts and crosscuts. The principal levels are the 125-, 225-, and 400-foot levels. About 450 feet southeast of the shaft on the 400-foot level, a 100-foot winze was sunk, and a small ore shoot below the main ore shoot was stoped from the 485-foot sub-level. The surface plant includes a 50-ton mill equipped with jigs, tables, and flotation cells; a steel headframe; and several other buildings.

Alpine Mine. Location: secs. 15 and 16, T. 12 N., R. 10 E., M. D., 2 miles southeast of Georgetown. Ownership: Elizabeth F. Burks, 4240 12th Street, Sacramento.

AFTER 7TH ANNUAL REPORT, BEEBE GOLD MINING CO, 1939

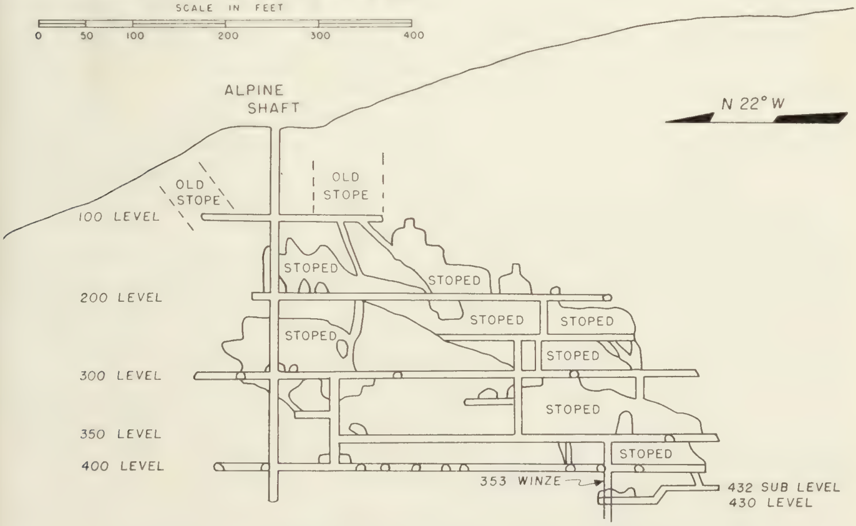


FIGURE 15. Longitudinal projection of underground workings of the Alpine gold mine.

The Alpine gold mine was worked originally in the late 1860's (Logan, 1934, p. 15). In 1888, a 10-stamp mill was in operation on the property. The mine was active around 1902 and again about 1912 (Logan, 1934, p. 15). From 1933 to 1938, the property was operated by the Beebe Gold Mining Company, and the ore was treated at the Beebe mill. A total of $434,665 was produced from 64,349 tons of ore in this last operation (Seventh annual report of the Beebe Gold Mining Company, 1939).

A gold-bearing vein of white sugary quartz strikes northwest and dips 60° to 65° NE. A number of south-dipping faults cross the vein and flat-dipping ore shoots, about 100 feet long, were found at these intersections (Logan, 1934, p. 15). Most of the gold was free and finely disseminated. Only minor amounts of sulfides are present in the ore. Country rock is amphibolite.

The mine is developed by a 400-foot shaft with levels at 100, 200, 300, 350, and 400 feet. There also is a 430-foot sublevel. The ore was trucked to the Beebe mill at Georgetown.

Argonaut Fraction Mine. Location: sec. 17, T. 12 N., R. 10 E., M. D., by Georgetown Creek, a quarter of a mile northeast of the Argonaut mine and 1½ miles east of Greenwood. Ownership: Pete Lopez, 4833 9th Avenue, Sacramento.

This gold property has been operated intermittently since 1933 by Mr. Lopez. Small amounts of ore are produced and stockpiled at the mine.

Two parallel northwest-striking veins about 150 feet apart have been developed. The ore consists of mineralized green schist with considerable amounts of pyrite. The veins range from 2 to 4 feet in width. One shipment of ore during 1937 averaged more than $15 per ton (Pete Lopez, personal communication, 1955).

A 100-foot drift adit has been driven southeast along the east vein and a 60-foot adit along the west vein. Several hundred tons of ore have been stockpiled. Two men work intermittently at the mine.

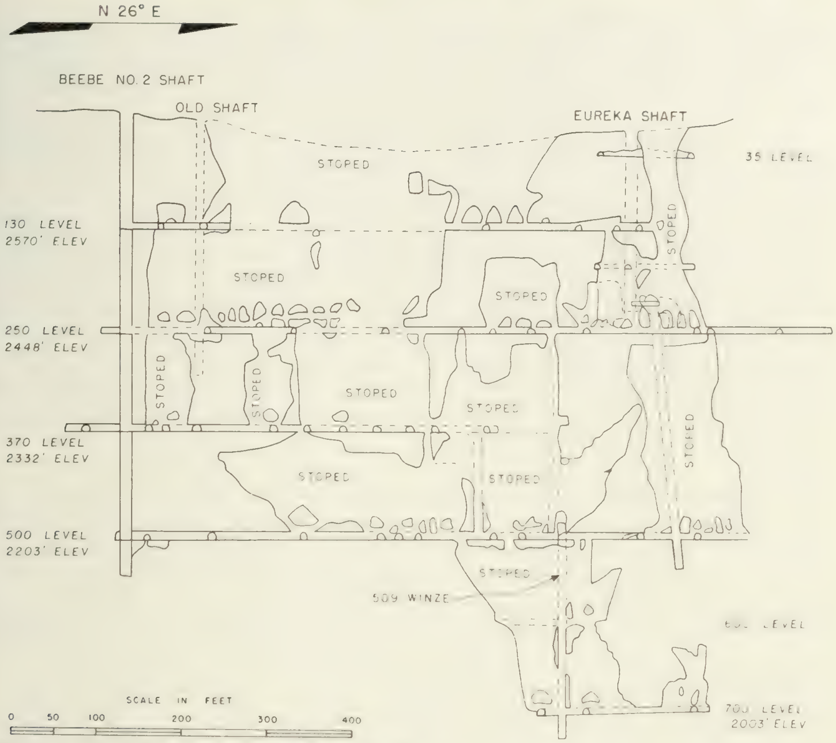
Barnes-Eureka (Greenstone) Mine. Location: sec. 33, T. 10 N., R. 10 E., M. D., 2 miles northeast of Shingle Springs. Ownership: B. F. Baskin, Route 2, Box 38, Placerville.

Originally worked prior to 1894 (Crawford, 1894, p. 102), the Barnes-Eureka mine was the source of small amounts of gold in 1912. Some work was done on the property in 1936 (Logan, 1938, p. 217). The property was worked on a small scale again during 1947-49 by B. F. Baskin of Placerville.

Gold associated with arsenopyrite and tellurides is in a 2-foot quartz vein on the contact between serpentine on the east and fine-grained metavolcanic rocks on the west. The vein strikes north and dips 45° E. The property is developed by a 350-foot inclined shaft with levels at 100 and 200 feet and a second 250-foot shaft to the south.

Beebe (East Lode, Brooklyn, Iowa, Woodside-Eureka) Mine. Location: secs. 2, 3, and 11, T. 12 N., R. 10 E., M. D., on the north side of Georgetown. Ownership: Woodside-Eureka Mining Company, Ltd., 1605 Tribune Tower, Oakland 12.

The Beebe mine, which is a consolidation of a number of claims, was one of the larger sources of gold in the county. The Eureka claim


N 26° E
BEEBE NO. 2 SHAFT
OLD SHAFT
EUREKA SHAFT
35 LEVEL
STOPED
130 LEVEL
2570' ELEV
250 LEVEL
2448' ELEV
370 LEVEL
2332' ELEV
500 LEVEL
2203' ELEV
509 WINZE
600 LEVEL
700 LEVEL
2003' ELEV
SCALE IN FEET
0
50
100
200
300
400

AFTER 7TH ANNUAL REPORT, BEEBE GOLD MINING CO., 1939

Figure 16. Longitudinal projection of the underground workings of the Beebe gold mine, showing stoped areas.

was first worked in the early days of the gold rush and later at intervals until 1908 (Logan, 1934, p. 17). The Beebe claim was first prospected in 1917 (Logan, 1934, p. 17). From 1932 to 1939, the property was operated by the Beebe Gold Mining Company. A total of $1,200,465 was produced from 306,241 tons of ore during this operation (Seventh annual report of the Beebe Gold Mining Company for 1939). After 1939, there was only a small amount of gold produced, and it was from cleanup operations. Ore from the Alpine mine also was treated at the mill (see Alpine gold mine).

The Beebe-Eureka vein is a silicified and mineralized zone in amphibolite schist that strikes northeast and dips 80° SE. The zone of mineralization ranges from 5 to 50 feet in width, but the average is 12 to 15 feet. On the footwall side of the ore zone is a dike of light-colored diorite 1 to 2 feet in width. Also present in the ore zone are a number of narrow basic dikes.

The mine is developed by three shafts, the Eureka, old Beebe, and Beebe No. 2 shafts. Levels were driven at 130, 250, 370, 500, 600, and 700 feet. On the 370-foot level, a length of 700 feet was drifted in ore (Logan, 1938, p. 217). A winze was sunk from the 500-foot level to the 700-foot level. The last production in the mine was from stopes driven from the 600- and 700-foot levels. Shrinkage stopes were employed.

Ore from this mine and the Alpine mine was treated in the mill, which could handle up to 250 tons per day (Logan, 1938, p. 218).

Flotation was employed, and the flotation concentrates were treated by cyanidation (Logan, 1934, p. 209). The mill originally was equipped with two Hadsell mills which later were replaced by conical ball mills. An average of 20 men worked at the mine and mill.

Big Canyon (Oro Fino) Mine. Location: sec. 29, T. 9 N., R. 10 E., M. D., 4½ miles south of Shingle Springs in Big Canyon. Ownership: Capitol Company, 1 Powell Street, San Francisco.

One of the larger gold producers in the county, the Big Canyon mine, originally was active prior to 1888 (Irelan, 1888, p. 174). Between 1893 and 1901, the mine produced $720,000 (Logan, 1938, p. 220). The property was idle until around 1915, when some development work was done (Tucker, 1919, p. 293). In 1934, the property was acquired by the Mountain Copper Company. This concern sank a new shaft, erected a mill, and operated the mine on a large scale until 1940. The total gold output during this last operation was $2,368,000 (Mountain Copper Company, personal communication, 1956). The mine has been idle since 1940.

The deposit which is in the West gold belt, is in a shear zone with amphibolite to the west and a serpentine lens to the east. East of the serpentine are metasedimentary rocks of the Calaveras group. The ore body is a vein-like mass of sheared and brecciated meta-andesite containing free gold, pyrite, pyrrhotite, albite, quartz, ankerite, and arsenopyrite. It merges into the amphibolite. The gold is in the quartz, pyrite, and pyrrhotite. The best ore was found to consist of equal parts albite, ankerite, and quartz, of which the albite appeared to be highly favorable for gold deposition (Logan, 1938, p. 220). Free gold constituted about 20 percent of the total gold contained, the remainder being combined with pyrite and pyrrhotite (Huttl, 1935, p. 217). Ore yielding $5 or more per ton was considered satisfactory.

The ore body strikes north to N. 25° E. and dips 35° to 40° E. and SE. The ore shoot that was mined during the 1930's had a maximum length of 450 feet and was as much as 60 feet wide.

The mine originally was developed by a vertical shaft sunk to a depth of 200 feet and then sunk an additional 540 feet on a 40° incline to the east. The ore was stoped out to the surface from the 500-foot level of this shaft during the early operations (Tucker, 1919, p. 293). The Mountain Copper Company sank a 620-foot shaft on a 45° incline, 400 feet north of the old shaft. Drifts were extended several thousand feet along the strike of the ore body. The ore was mined in open stopes. In 1937, some ore in the upper portion of the mine was mined by open pit methods.

From the mine, the ore was belt-conveyed to the mill. The mill had a capacity of 300 tons (Huttl, 1935, p. 217). The mill was equipped with two 7- by 6-foot ball mills, two Dorr classifiers, and five Fagergren flotation cells and a cleaner cell. Concentrate was sent through a Dorr thickener and an Oliver filter. Concentrates were shipped to the smelter at Tacoma. When in full operation, about 300 tons of ore per day were mined. A crew of 150 men worked at the mine and mill.

Big Sandy (James Marshall) Mine. Location: sec. 24, T. 11 N., R. 10 E., M. D., on the Mother Lode half a mile south of Kelsey. Ownership: H. J. Picchetti, 1115 Fairview Avenue, San Jose.

This gold mine is of historical interest as it was located originally by James W. Marshall (Logan, 1934, p. 19). It was active during the 1890's, and the ore was treated in a 10-stamp mill (Crawford, 1896, p. 134). During the 1930's the mine was worked for pocket gold, and several fine specimens of crystallized gold were found.

The deposit is on the Mother Lode belt in Mariposa slate. The vein, which is as much as 15 feet in width, consists of bands of quartz and ankerite. Associated with the vein are amphibolite schist, talc schist, and dike rocks. The vein strikes north-northwest and dips east. Most of the ore produced from the mine was low-grade with average values ranging from $1.75 to $2.25 per ton (Logan, 1934, p. 20). The specimen ore was obtained largely from seams in an altered dike.

The low-grade ore was mined from an open cut 750 feet long. The mine also is developed by a 340-foot vertical shaft with levels at 60, 120, 227, and 323 feet with crosscuts to the vein. The vein is cut by the shaft at a depth of 240 feet.

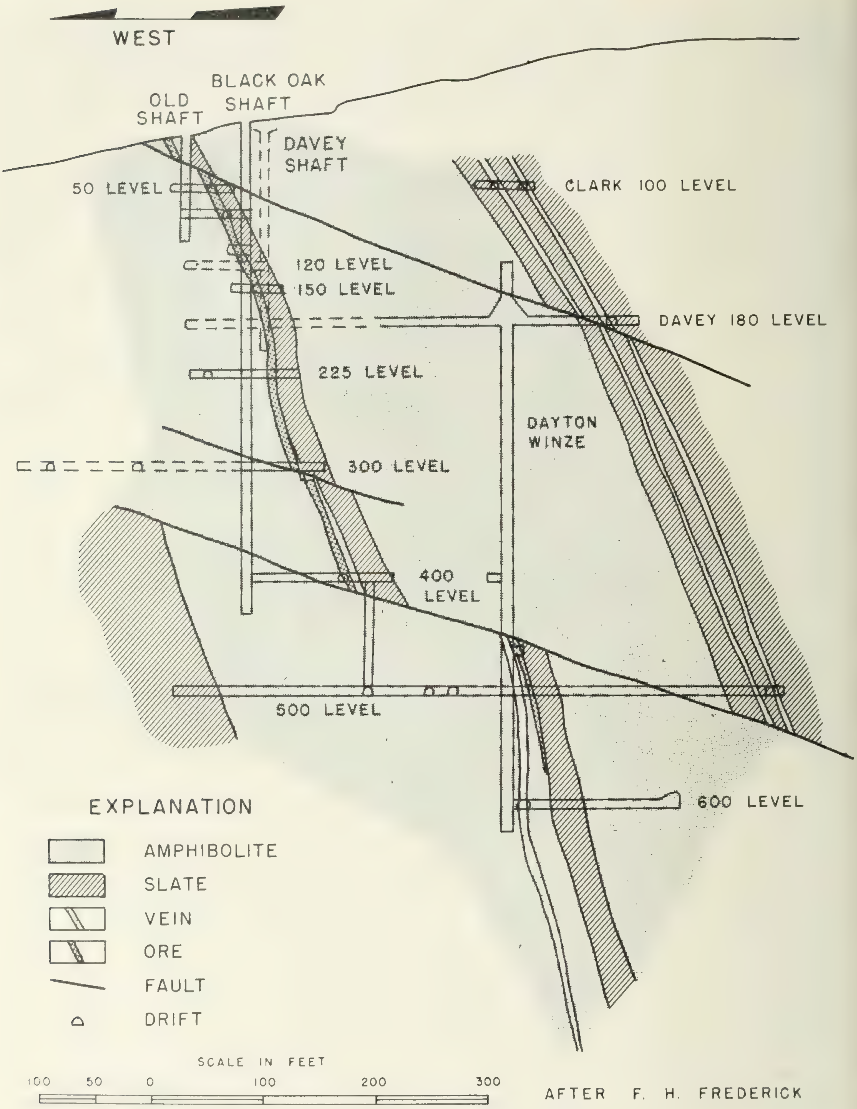
Black Oak (Clark, Davey, Dayton Consolidated) Mine. Location: sec. 34, T. 12 N., R. 10 E., M. D., at Garden Valley just south of the school. Ownership: R. J. Wilson, Garden Valley.

The Black Oak mine was worked originally as a pocket gold mine prior to 1934 (Logan, 1934, p. 20). In 1934, the mine was reopened by the present owner. A new shaft was sunk, a mill erected, and the property soon developed into one of the more important sources of gold in the county. Although the deposit is relatively shallow, an extensive amount of crosscutting was done. By 1937, more than $400,000 had been produced besides a considerable amount of gold that was believed to have been stolen by "high-graders" (Logan, 1938, p. 224). Operations continued until 1942, when the mine was shut down. It has been idle since. The total output of the mine is approximately $1,250,000 (F. H. Frederick, personal communication, 1955).

Between 1934 and 1938, the Dayton Consolidated Mines Corporation developed the Davey claim, which adjoins the Black Oak mine on the north and northeast, the Clark claim on the east, and the Davenport claim on the southeast. The Dayton shaft or winze was sunk on the Davey claim, and some ore was produced. These properties were merged with the Black Oak mine in 1938 (Logan, 1938, p. 224) and now are considered to be part of the Black Oak mine.

This deposit is just north of where the Mother Lode belt splits into two branches—one branch extending northwest through Greenwood, the other north through Georgetown. The structure of the general area of this deposit is characterized by tightly compressed, steeply plunging folds. Thrust faults dipping 20° to 35° E. have disrupted the contacts.

The Black Oak vein zone strikes northwest and dips steeply northeast. It lies in the mass of amphibolite schist that is between the two belts of Mariposa slate in this area. However, there is a strip of graphitic slate 50 feet wide that forms the hanging wall. The main ore shoot, which consisted of gold-bearing stringers and veins of calcite and quartz, was wide at the north end and pinched out to the south. It averaged 110 feet in length, had a vertical extent of 380 feet, and an average width of 12 feet; it pitched 80° S. The shoot followed or was near the contact between the graphitic slate and amphibolite. In the


WEST
OLD SHAFT
BLACK OAK SHAFT
DAVEY SHAFT
50 LEVEL
CLARK 100 LEVEL
120 LEVEL
150 LEVEL
DAVEY 180 LEVEL
225 LEVEL
DAYTON WINZE
300 LEVEL
400 LEVEL
500 LEVEL
600 LEVEL
EXPLANATION
AMPHIBOLITE
SLATE
VEIN
ORE
FAULT
DRIFT
SCALE IN FEET
100
50
0
100
200
300

AFTER F. H. FREDERICK

FIGURE 17. Cross-section of underground workings of Black Oak gold mine, showing veins.

upper levels of the Black Oak mine, it followed the contact and in the lower levels it was enclosed in amphibolite but near the slate. The vein began to veer away from the contact below the 500-foot level, and little ore was found below this level (see Fig. 17). Apparently, gold deposition was controlled by the slate (F. H. Frederick, personal communication, 1955). A number of low-angle thrust faults offset the vein and in some cases localized the gold mineralization. The principal fault offset the vein and ore shoot for about 200 feet between the 400- and 500-foot levels. Only about $100,000 was produced from the ore shoot below this fault (F. H. Frederick, personal communication, 1955).

About 250 feet east of the Black Oak vein is the Clark vein zone, which is in slate. To the north the veins converge with the slate-amphibolite contact. The vein matter consists of quartz with feldspar, calcite, and appreciable amounts of pyrite. Pyrite also is present in the slate wall rock. About 100 feet east of the Clark vein is the Davenport vein zone, from which there was a small amout of ore produced. These two veins also are cut by the thrust faults.

The main working entry is the 400-foot vertical Black Oak shaft. The Dayton shaft, which actually is a vertical winze, was sunk from the 175- or the Davey 180-foot level to the 600-foot level 225 feet east of the Black Oak shaft. There are about 6000 feet of drifts and crosscuts. Crosscuts extend east from the Dayton shaft to the Clark vein zone, but there has been very little stoping in this portion of the mine. Other shafts on the property include the 180-foot Davey shaft to the north and the 100-foot Clark shaft to the south. A 180-foot crosscut extends east from the Clark shaft to the Clark vein zone.

During the later operations the ore was treated in a 35-ton mill which included primary crushers, Williamson ball mill, Dorr classifier, a hydraulic trap later replaced by a Denver jig, and three Fagergren flotation cells.

Blue Gouge (Berg) Mine. Location: sec. 21, T. 10 N., R. 13 E., M. D., by Camp Creek 6 miles north-northwest of Grizzly Flat. Ownership: Americo and Columbus Sciaroni, Grizzly Flat.

In 1896, the Blue Gouge gold mine was extensively prospected by Mackay, Flood, and associates of San Francisco (Crawford, 1896, p. 135). However, this work was abandoned soon afterward (Logan, 1938, p. 225). Later some work was done on the property by the present owners, ending about 1925 (Americo Sciaroni, personal communication, 1955). A small amount of work was done again about 1936 (Logan, 1938, p. 225).

The deposit consists of a zone of parallel gold-bearing quartz veins in slate and chlorite schist. Some of the slate and schist was gold bearing. The ore zone is as much as 400 feet wide and is exposed for a length of 3500 feet. It strikes northwest and dips northeast. The quartz veins range from 6 to 16 feet in width. The footwall is slate, the hanging wall granodiorite. The grade of ore in the principal veins averaged $7 per ton in gold at the old price, and the mineralized slate and schist was somewhat less valuable (Crawford, 1896, p. 135). The mine is developed by seven crosscut adits ranging from 120 to more than 300 feet in length.

Briarcliffe (Baldwin, Last Chance, National) Mine. Location: secs. 1, 2, 11, and 12, T. 8 N., R. 10 E., M. D., 1 mile southeast of Nashville. Ownership: Nick Neilsen, Box 100, Diamond Springs.

The Briarcliffe gold mine, which consists of the Last Chance claim on the north and the Baldwin claim on the south was active in the 1890's (Crawford, 1894, p. 102). The Last Chance claim again was active in 1909, when a 10-stamp mill was in operation (Logan, 1938, p. 226). The Baldwin claim was reopened about 1914, and some gold was produced (Tucker, 1919, p. 280). In 1932, these properties were obtained by Briarcliffe Mines, Ltd. and operated from 1932 to 1936 and again during 1940-41. Most of this later work was in the Baldwin claim.

Although the deposit is a mile east of the Mother Lode, its veins and ores are similar. The vein, which strikes N. 10° E. and dips 60° to 72° SE., has an amphibolite hanging wall and slate footwall. The average width of the vein is 15 feet. The best ore was on the hanging wall side of the vein and extended into the amphibolite. Up to 1936, more than 30,000 tons of ore that yielded $3 to $4 per ton had been mined (Logan, 1938, p. 226).

The mine is developed by a 200-foot inclined shaft, a northeast drift adit that is connected with the shaft, and a 500-foot winze sunk from the adit about 500 feet in from the portal. Most of the ore mined in later operations was from the area of the winze. The ore was treated by flotation in a 100-ton mill.

Church Mine. Location: sec. 12, T. 9 N., R. 10 E., M. D., on the Mother Lode belt 2 miles southeast of El Dorado by Deadman Creek. Ownership: Madre de Oro Gold Mines Company, Box 925, Corcoran.

One of the better-known Mother Lode gold mines in El Dorado County, the Church mine was first worked on a small scale about 1850 (DeGroot, 1890, p. 171). During the 1860's, it was consolidated with the Union mine, which lies to the south and was later worked separately (see Union mine). By 1868, these properties had produced more than $600,000 (Logan, 1934, p. 42). The mine was worked extensively during the 1880's and 1890's. By 1896, it had been developed to a depth of 1200 feet, and the ore was treated in a 10-stamp mill (Crawford, 1896, p. 137). In 1900, the mine was 1350 feet deep (Storms, 1900, p. 92). In 1907, it was shut down (Logan, 1926, p. 413).

In 1941, the mine was reopened by the Madre de Oro Mining Company. The shaft was rehabilitated, a new surface plant built, and a 20-stamp mill with flotation erected. Production figures of the U. S. Bureau of Mines Minerals Yearbook for 1941 show that 496 tons of ore were milled, from which 169 ounces of gold were recovered. The mine was shut down in 1942 and has been idle since.

In the spring and summer of 1953, the 20-stamp mill was used as a custom chrome mill by El Dorado Chrome Company (see El Dorado Chrome Company in Chromite section). Late in 1953 and early 1954, the mill was used by the North American Tungsten Company to treat tungsten ore that was trucked in from the Garnet Hill mine in eastern Calaveras County.

The three main parallel veins are enclosed in Mariposa slate. They range from 5 to 10 feet in thickness, strike north to northeast, and dip steeply east or southeast. The principal work and largest amount of production was from the middle or Kidney vein. The west vein contains only low-grade material. Some work was done on the east vein in the Union mine, which is just south of the Church mine.

The Kidney vein strikes north between the surface and the 350-foot level. Below this level the strike swings to the northeast. From the 350- and 500-foot levels, the vein dips 45° E., but below the 500-foot level it steepens to 74° SE. A number of kidney-shaped ore shoots were developed between the surface and 500-foot level. The main ore shoot was continuous between the 500- and 1200-foot levels; below the 1200-foot level, the grade decreased greatly (Tucker, 1919, p. 283).

The best ore, as high in grade as $30 per ton (Storms, 1900, p. 92), was mined during the earlier operations. Ore milled from as far down as the 1300-foot level had averaged $17 per ton (Logan, 1934, p. 22). However, below that level it decreased to $4 per ton or less. Sulfides formed 1½ to 2¼ percent of the ore and assayed as high as $140 per ton in gold (Logan, 1934, p. 22). Considerable amounts of gouge were present, especially in the lower levels. Some of the gouge carried some gold.

The mine is developed by a 1200-foot vertical shaft, with crosscuts to the vein. Levels are at 100, 200, 300, 350, 500, 600, 700, 850, 1000, and 1200 feet. On the 1200-foot level, a 670-foot crosscut extends east to the vein, from which a winze was sunk on the vein to the 1400-foot level. On the 600- and 1200-foot levels, drifts extend north and south to the property line.

There is an extensive surface plant including a machine shop, living quarters, a warehouse, and a conveyor belt running from the bins on the steel headframe to the mill. The 20-stamp mill is equipped with Deister tables and a flotation circuit.

Cosumnes (Melton, Middle End) Mine. Location: secs. 3 and 4, T. 9 N., R. 13 E., M. D., 2½ miles north of Grizzly Flat. Ownership: Caldor Lumber Company, Diamond Springs.

The Cosumnes gold mine was active during the 1880's, and the ore was treated in a 15-stamp mill (Irelan, 1888, p. 179). In these early operations, it was known as the Melton mine. The property was active again in 1894 (Crawford, 1894, p. 117). The mine was reopened in 1928 as the Middle End mine (Logan, 1938, p. 238) and was operated almost continuously until 1942. In 1938, Cosumnes Mines, Inc. was organized. The mine was reopened in 1945 and operated by this concern until 1950 when it was purchased by the present owner.

Most of the ore was mined from the main or Middle End vein, which strikes north-northeast and dips steeply west. The vein has an average width of 3 feet. Country rock is granodiorite. A number of ore shoots were worked. Appreciable amounts of galena and pyrite with sphaleriate, chalcopyrite, stibnite, and arsenopyrite are present in the ore. During the last years of operation, the ore contained as much as $25 per ton in gold (Columbus Sciaroni, personal communication, 1955). Sulfide concentrates yielded from $100 to $200 per ton in gold (Logan, 1938, p. 238).

The mine is developed by a 380-foot southwest crosscut adit to the vein and several thousand feet of drifts. The ore was treated in a 60-ton mill equipped with amalgamation and flotation units and the flotation concentrates trucked to a smelter.

Crystal (El Dorado Crystal) Mine. Location: sec. 18, T. 9 N., R. 10 E., M. D., 3 miles south of Shingle Springs and half a mile south of Frenchtown. Ownership: F. W. Barrette, Shingle Springs.

This gold mine was originally worked prior to 1890. During the early 1890's, the mine was worked through a 250-foot inclined shaft and 350-foot crosscut adit. The ore was treated in a 10-stamp mill (Crawford, 1894, p. 108). After being idle for many years, the mine was reopened in 1937 by Ben Lockwood of Shingle Springs (Logan, 1938, p. 228). Also a new mill was erected. The mine was operated until 1940 and has been idle since.

The deposit lies in the West Gold Belt. It consists of an irregular, north-trending quartz vein as much as 12 feet wide. Country rock is amphibolite-chlorite schist. Gabbrodiorite lies to the west. Apparently the vein material was deposited in irregular cracks and occasional cavities, which resulted from the intrusion of the gabbrodiorite into the schist (Logan, 1938, p. 228). There are a number of small open cavities in the vein in which euhedral quartz crystals have grown. The vein matter consists of quartz, feldspar, calcite, and pyrite. The ore contained as much as $11 per ton in gold (Logan, 1938, p. 229).

The mine is developed by a 250-foot inclined shaft and a 1,028-foot adit driven north. A 480-foot inclined winze with levels at 200, 326, and 456 feet was sunk from the adit 328 feet in from the portal. An ore shoot ranging from 8 to 24 feet in width and up to 280 feet long was developed on the 326-foot level.

The mill had a capacity of 125 tons of ore per day. It was equipped with a ball mill and a cyanidation unit.

French Creek Mine. Location: sec. 31, T. 9 N., R. 10 E., M. D., 3½ miles northeast of Latrobe. Ownership: William Lange and L. W. Loomis, Placerville.

This gold property has been under development since 1953. The operators are sinking an inclined shaft, which was 30 feet deep early in 1956. A surface plant, including a headframe and milling equipment, is being installed.

The deposit, which is in a belt of metavolcanic rock west of the Mother Lode gold belt, is several hundred yards south of the old Brandon mine. The ore body is dark green, fine- to medium-grained metadiabase with disseminated auriferous pyrite and some fine free gold. Minor amounts of chalcopyrite and a trace of arsenopyrite are present.

Strike of the ore body is north, and dip is 65 to 68° E. The ore body has been traced for about 300 feet along the strike, and its average width is 20 feet. Assays range from $2.80 to $60 per ton in gold. The estimated average is $20 to $30 (William Lange, personal communication, 1954). The shaft is sunk in the footwall of the ore body.

Funny Bug (Pendelco) Mine. Location: sec. 5, T. 10 N., R. 10 E., M. D., 1 mile southwest of Gold Hill on the north bank of Webber Creek. Ownership: R. V. Montgomery, Route 2, Box 193-K, Placerville.

This mine was active intermittently from 1928 to 1942 and yielded small amounts of gold and copper. In 1953, the property was leased by Carl Howe of Placerville who did a small amount of rehabilitation work and surface exploration.

Two northeast-striking veins lie in a contact metamorphic zone of greenstone, mica schist, and granodiorite. The ore consists of parallel bands of pyrite and chalcopyrite associated with quartz and magnetite. Bornite, specular hematite, sphalerite, molybdenite, arsenopyrite, stibnite, and galena are also present (Logan, 1938, p. 242). The mine is developed by crosscuts on two levels from a 200-foot shaft sunk near the main vein.

Grand Victory Mine. Location: secs. 33 and 34, T. 10 N., R. 11 E., M. D., on Squaw Creek 4 miles southeast of Diamond Springs. Ownership: Provident Minerals Corporation, c/o Floyd Singleton, 459 Turk Street, San Francisco 2.

This gold mine first was worked in 1857, and in 1879 the ore was treated in a five-stamp mill (Logan, 1938, p. 231). By 1888 extensive open cuts and underground workings had been developed, and the mill had been enlarged to 40 stamps (Irelan, 1888, p. 194). In 1894, a cyanidation plant was installed and was operated until 1901 when the mine was shut down. During the 1930's, a considerable amount of prospecting and sampling was done on the property, and a number of drifts and crosscuts were driven.

The deposit is a few miles east of the Mother Lode. Country rock is silicified schist, slate, quartzite, and limestone of the Calaveras group. The ore consists of silicified schist and slate with quartz seams containing free gold, pyrite, and smaller amounts of arsenopyrite. The strike of the ore bodies varies from northwest to northeast, and in some places it cuts the schistosity of the enclosing rock. The ore bodies are as wide as 100 feet (Crawford, 1894, p. 112). Much of the ore mined during the early operations was highly weathered material. There are a number of diorite dikes parallel to the ore bodies.

The mine is developed by a 500-foot drift adit and open cuts as wide as 135 feet, which extend over 500 feet along the strike. About 450 feet in from the adit portal is a winze with levels at 100, 200, and 300 feet. There are several thousand feet of drifts and crosscuts.

Grit (Liddicoat, Spanish Dry Diggings) Mine. Location: sec. 29 T. 13 N., R. 10 E., M. D., at Spanish Dry Diggings, 4 miles north of Greenwood. Ownership: Liddicoat Gold Mines, Inc., Route A, Box 27, Greenwood; J. L. Liddicoat, president.

This gold mine is at the north end of the west branch of the Mother Lode. The mine was highly productive around 1852 and between 1860 and 1867, yielding $100,000 (Logan, 1934, p. 46). In 1865, a mass of crystallized gold weighing 101.4 ounces Troy was found on the property. The mine was active again from 1919 to 1922 (Logan, 1922, p. 44). The total output of the property up to this time was about $300,000. The present owners operated the mine almost continuously from 1945 to 1952 and produced a total of $34,000 (J. L. Liddicoat, personal communication, 1955).

The deposit consists of gold-bearing quartz and calcite veins and veinlets in amphibolite schist and Mariposa slate. The upper portion of the deposit is highly decomposed and was worked by hydraulicking to depths of 125 to 150 feet in the early days. Such ground contained as much as $2 to $3 per cubic yard (Logan, 1920, p. 426). Three parallel veins composed of quartz and calcite strike N. 20° W., dip 80° NE., and have been explored by underground workings. The veins pinch and swell abruptly and range from a few feet to as much as 20 feet in thickness. Considerable amounts of coarse crystalline pyrite are present. Small patches of serpentine are exposed west of the west vein.

All of the ore mined since 1945 has been from the west vein which is developed by an 800-foot southeast drift adit. About 400 feet in from the adit portal, crosscuts were driven 70-feet west and 40-feet east. The vein has been stoped for a distance of 125 feet, beginning about 275 feet in from the adit portal. This stope raises into the open cut that was hydraulicked in the early days. The ore was trammed out the audit to the mill which lies just north of the portal.

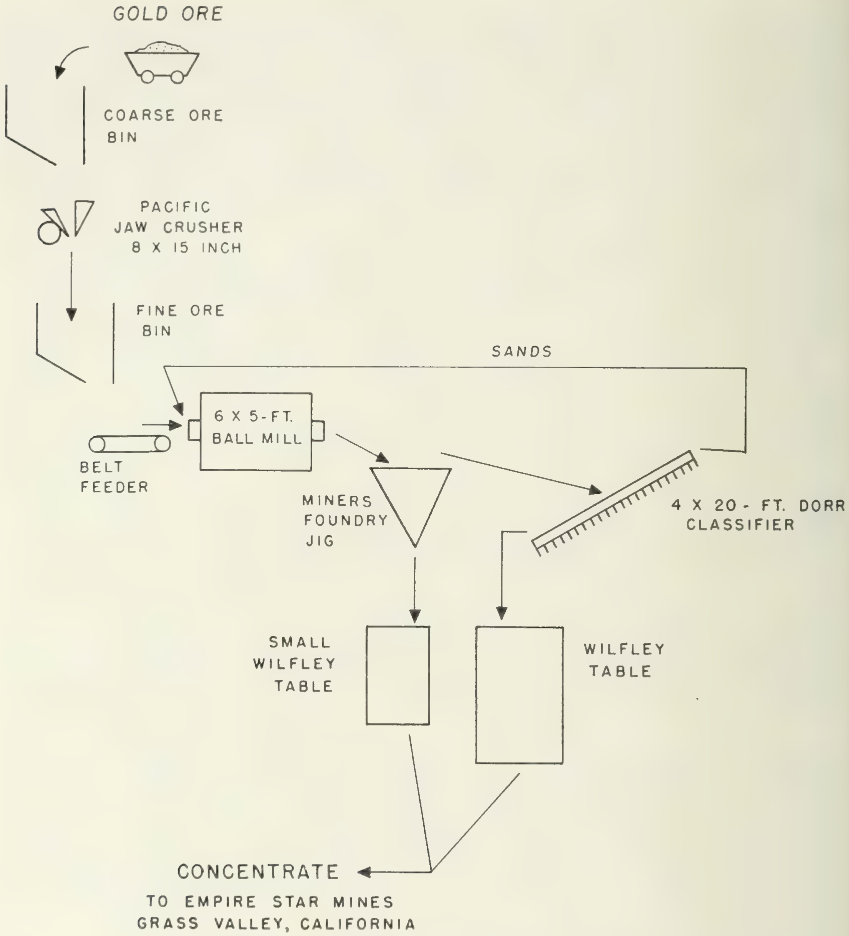

GOLD ORE
COARSE ORE BIN
PACIFIC JAW CRUSHER 8 X 15 INCH
FINE ORE BIN
SANDS
6 X 5-FT. BALL MILL
BELT FEEDER
MINERS FOUNDRY JIG
4 X 20-FT. DORR CLASSIFIER
SMALL WILFLEY TABLE
WILFLEY TABLE
CONCENTRATE
TO EMPIRE STAR MINES
GRASS VALLEY, CALIFORNIA

FIGURE 18. Mill flowsheet of Grit gold mine.

At the mill, which has a capacity of 80 tons, the ore was concentrated by jigging and tabling. Concentrates were sold to the Empire-Star mine at Grass Valley. The mill heads averaged $18 per ton in 1952 (J. L. Liddicoat, personal communication, 1953).

Hazel Creek Mine. Location: sec. 3, T. 10 N., R. 13 E., M. D., 2 miles southeast of Pacific House on Hazel Creek and 15 miles east of Placerville. Ownership: Fay. M. R. Gunby, Box 752, Placerville, leased by Hazel Creek Mining Corporation, P. O. Box 508, North Sacramento, Richard Ronne, president and Ray Graetz, superintendent.

The Hazel Creek mine has been active continuously since 1948 and is the largest gold mining operation in El Dorado County. In 1948 the vein was discovered in a logging road cut (Earl Estey, former superintendent, personal communication, 1954). Soon afterward, an adit was driven and a mill erected. At the present time, 30 to 40 tons of ore per day are being mined and milled.

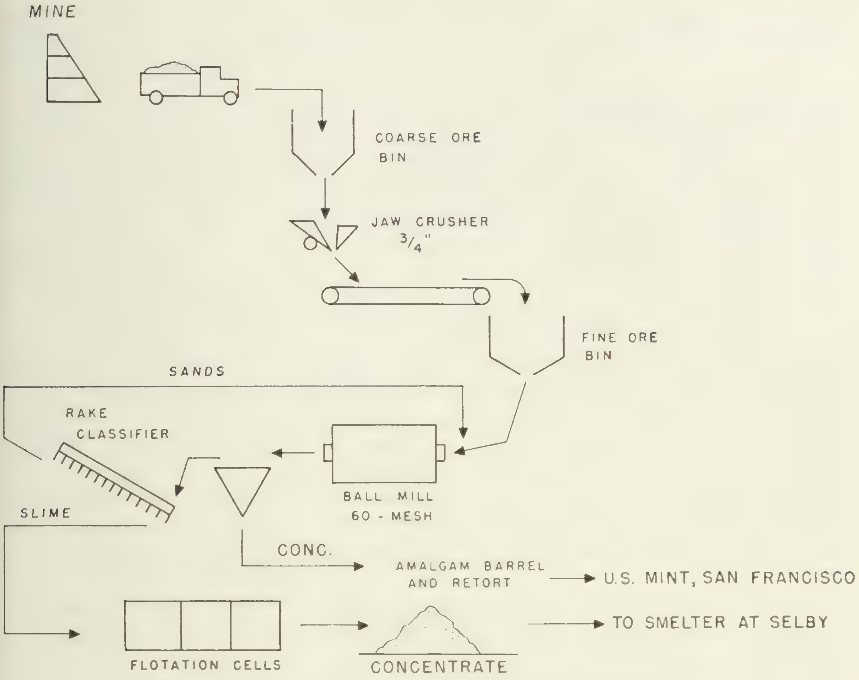


FIGURE 19. Mill flowsheet, Hazel Creek gold mine, Hazel Creek Gold Mining Company.

This is an East Belt gold deposit. There are two principal gold-bearing quartz veins that are nearly parallel and about 40 feet apart. They have a north-northwest strike. The east vein has an average dip of about 85° E. and joins the vertical west vein above the adit portal. The west vein is 5 to 6 feet wide, while the east vein ranges from 5 to 12 feet in width. There are numerous quartz stringers parallel to the principal veins especially in the south portion of the deposit. About 300 feet south of the adit portal, a southeast-striking cross vein several feet wide extends from the east to the west vein. In the north portion of the mine, the east vein enters a shear zone where there are considerable amounts of gouge. Here the strike swings to the east, and the width of the vein narrows to less than a foot. Country rock is interbedded slate and green schist with smaller amounts of quartzite and metachert, all of which are part of the Calaveras group. A number of post-mineral dikes of fine- to medium-grade diorite and quartz diorite cut both the veins and country rock.

The ore consists of native gold with considerable amounts of galena and pyrite in quartz, and smaller amounts of chalcopyrite and sphalerite. The free gold usually is associated with the galena. Considerable amounts of high-grade ore were produced from the area where the two main veins join in the upper level and where the cross vein intersects the east vein. (Ray Graetz, personal communication, 1955).

The mine is developed by a 500-foot drift adit driven south on the west vein and a 130-foot inclined two-compartment shaft sunk on the west vein near the adit portal. The 100-foot level, which is now 700

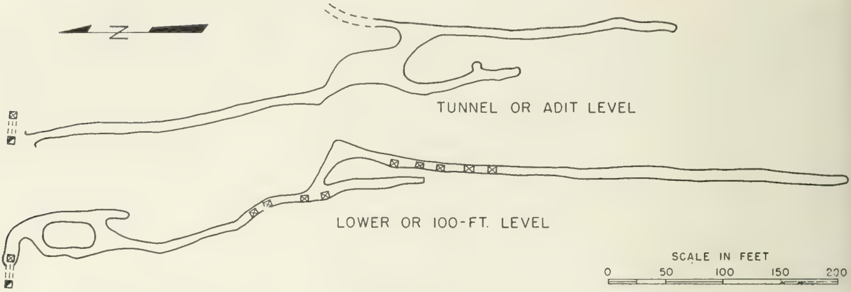


FIGURE 20. Map of underground workings of Hazel Creek gold mine.

feet long, is connected with the adit level by raises and stopes. The veins are mined by shrinkage stopes. Lightweight Swedish Atlas Copco drills with tungsten carbide inserts are used in drilling. Seven-foot holes are used for development headings and 5-foot holes are used in the stopes. Forty percent gelatin dynamite and electric caps are used for blasting. Early in 1956, most of the ore was being produced from an extensive stope in the south portion of the 100-foot level on the west vein. This stope is about 300 feet long, 50 feet high, and averages 10 feet in width.

Ore from the mine is treated at the mill which is on the north bank of Hazel Creek. The mill, which employs flotation, has a capacity of 30 tons per day. The free gold is amalgamated and retorted, and the sponge gold is sent to the smelter at Selby. The sulfied concentrate from the flotation cells is dried and also sent to Selby. The sulfide concentrate may assay as high as $500 per ton in gold and silver (Earl Estey, personal communication, 1954). From 10 to 15 men work at the mine and mill.

Kelsey (Lady) Mine. Location: secs. 24 and 25, T. 11 N., R. 10 E., M. D., half a mile southeast of Kelsey. Ownership: A. D. O. Crabtree, 616 North F Street, Porterville.

The Kelsey gold mine was worked originally prior to 1915 (Tucker, 1919, p. 289). In 1926, the Kelsey Mining Company was formed which reopened the mine and erected a mill (Logan, 1934, p. 29). It was active until 1931. The mine was reopened again in 1934, the mill altered, and was operated until 1941.

The deposit is in Mariposa slate associated with narrow bands of amphibolite and serpentine. The ore consists of schist and slate with quartz containing free gold, pyrite, and some galena. Considerable amounts of ankerite are present. The rocks in this area trend northwest. The formations are much disturbed by faulting. The ore mined during 1928-31 yielded from $1.80 to $6.40 per ton (Logan, 1934, p. 29), while much of the ore mined later on was even lower in value (Logan, 1938, p. 235).

The mine is developed by a main 1700-foot north drift adit and a 700-foot north drift adit about 300 feet above the main adit. These two adits are connected by a raise. Also there is a 42-foot shaft near the main adit portal.

The mill first erected by the Kelsey Mining Company had ten stamps, a Williamson ball mill, classifier, four Kraut flotation cells, and a cleaner cell. Later the stamps were replaced by a Telsmith gyratory crusher and Aurora jaw crusher. Also a Pan-American jig was added. About 40 tons of ore per day were milled.

Larkin (Diamond Springs) Mine. Location: sec. 29, T. 10 N., R. 11 E., M. D., on the Mother Lode 1 mile east of Diamond Springs. Ownership: Bernard B. Ball, 122 Bedford Avenue, Placerville.

The Larkin gold mine also has been a source of copper ore. It is noted for the large dolomitic vein on the property. The mine was active in 1896 when it was developed by a 250-foot vertical shaft (Crawford, 1896, p. 148). The ore was treated in a five-stamp mill. By 1900 the shaft had been extended to a depth of 600 feet, and the mill had been increased to 10 stamps (Storms, 1900, p. 93). The shaft later was extended to 800 feet in depth. In 1903, the mine was shut down. It was reopened in 1918, and some copper ore was produced (Logan, 1926, p. 407). The total output of the mine is estimated to be $125,000 (Logan, 1934, p. 30).

Several gold-bearing quartz veins are in the hanging wall side of a large mass of dolomite. This large mass of dolomite material, which is as much as 80 feet wide, contains iron oxide, and has also been classed as ankerite (Storms, 1900, p. 93). It is partially altered to talc schist, and is cut by dikes of diabase. Country rock on both sides of it is Mariposa slate. The veins have a north-northeast trend. The principal productive vein ranged from 4 to 12 feet in width and contained 1½ percent pyrite (Logan, 1934, p. 30). Chalcopyrite and malachite are also present. Several ore shoots that contained as much as 10 percent copper were developed (Aubury, 1908, p. 217). A west vein, about 7 feet wide, was prospected on the 400-foot level.

Martinez (Hillside Group) Mine. Location: secs. 12 and 13, T. 9 N., R. 10 E., M. D., on Martinez Creek south of the Union mine about 4½ miles southeast of El Dorado. Ownership: Martinez Gold Mines Company, P. O. Box 61, El Dorado.

In 1915, the Martinez gold mine was operated by the Hillside Gold Mining Company (Tucker, 1919, p. 288). It was worked on a small scale around 1926 (Logan, 1926, p. 415) and again during the early 1930's. In 1937, some development work was done in the lower workings of the mine, and a small amount of ore was produced (Logan, 1938, p. 237).

This deposit consists of a series of parallel veins on the east side of the belt of Mariposa slate that contains the Mother Lode in this area. The veins are in slate and at the contact with the Calaveras formation that lies to the east. The veins strike N. 20° E. and dip 70° SE. Interbedded layers of greenstone are associated with the veins; mariposite and ankerite are also present. The ore mined in 1917 yielded $4.12 per ton (Logan, 1938, p. 412).

The mine is developed by a 600-foot crosscut adit driven west with numerous raises and drifts. South of this is a 600-foot crosscut adit and on the hill above are a number of older workings. The ore was treated in a five-stamp mill.

Monarch-Sugar Loaf Mine. Location: sec. 27, T. 9 N., R. 10 E., M. D., 3 miles northwest of Nashville. Ownership: leased by George Ross, Placerville.

The Monarch-Sugar Loaf gold mine was worked originally in the 1850's (George Ross, personal communication, 1955). The mine was active between 1870 and 1907, and the ore was treated in a 10-stamp mill. During the 1930's, some prospecting was done on the property. In 1953-54, the mine was leased by J. H. Wren and associates of Sacramento who rehabilitated some of the workings. Early in 1955, George Ross and associates leased the mine; they since have mined some high-grade ore from small pockets in the vein.

The quartz vein is in fine-grained meta-andesite of the Logtown Ridge formation (upper Jurassic). It has a north to northwest strike and a flat dip to the west and southwest. Near the surface, the gold is chiefly in small but rich ore shoots with little or no sulfides. Much of the recent output has been specimen material. The amount of sulfides present in the ore increased at depth (George Ross, personal communication, 1955). Chalcopyrite and sphalerite are the most common sulfides; pyrite and galena ore present in smaller amounts. The most favorable areas for the occurrence of gold in the vein are where it swells, changes in strike or dip, and junctions with small stringers.

The deposit has been developed by open cuts and shallow shafts for about 2,000 feet along the strike. Present work is confined to a 70-foot crosscut adit, and several nearby open cuts in the central portion of the deposit. The ore is treated by hand-sorting, hand-mortaring, and amalgamation. Three men work intermittently at the mine.

Montezuma-Apex and Montezuma Extension Mine. Location: sec. 35, T. 9 N., R. 10 E., and sec. 2, T. 8 N., R. 10 E., M. D., just east of the Cosumnes River. Ownership: Montezuma-Apex Mining Company, c/o National Tunnel and Mines Company, 818 Kearns Building, Salt Lake City, Utah.

Originally worked at shallow depths during the early days of the gold rush, the Montezuma mine was active up to 1871 (Logan, 1934, p. 31). The mine was worked from 1890 to 1907 and again during 1914. From 1920 to 1928, there was some recorded output. In 1931, the Nashville Mines, Ltd. reopened the mine, and in 1933, they were succeeded by the Montezuma-Apex Mining Company which operated the property until 1939. This concern also operated the Havilah (Nashville) mine which lies just to the south.

The vein occurs in the Mother Lode belt and is largely in Mariposa slate. Small bands of greenstone are interbedded with the slate, and some parts of the hanging wall contain schist. Also there is a heavy gouge in portions of the footwall. The vein strikes north to northeast and has an average dip of 60° E. The mine is developed by a 1,540-foot inclined shaft and an older 360-foot inclined shaft 300 feet to the north. In the old workings an ore body 8 to 20 feet wide was stoped for a length of 250-feet down to the 120-foot level (Logan, 1934, p. 31).

In the newer workings, an ore shoot 150 feet long was mined north of the shaft between the 800- and 1,000-foot levels in 1914. When the mine was reopened in 1932, these levels again were worked. The shaft was then deepened, and a new ore shoot that was about 570 feet long and 4 to 6 feet wide was developed on the 1,200-foot level. Most of the later output was from this shoot. Also, a spur vein with a northwest strike entered the main vein from the east side near the shaft and was mined between the 900- and 1,100-foot levels. Below a depth of 1,225 feet, however, the ore decreased in grade (Logan, 1938, p. 239). The 1,500-foot level was extended 1,050 feet south under the Nashville mine, which is 1,000 feet to the south, with the object of encountering the Havilah (Nashville) vein.

Ore from the mine originally was treated in a 10-stamp mill. This was replaced in 1933 by a 240-ton mill equipped with two Marcy ball mills, hydraulic traps, Wilfley tables and a 10-cell flotation unit (Logan, 1934, p. 206).

Mount Pleasant Mine. Location: sec. 16, T. 9 N., R. 13 E., M. D., 1 mile west of Grizzly Flat. Ownership: Annie S. Kirk, Box 507, Placerville.

The principal source of gold of the Grizzly Flat district, the Mount Pleasant mine, first was worked in 1851, although the output at that time is unknown (Logan, 1926, p. 416). From 1874 to 1914, the mine yielded $1,046,748 in gold (Logan, 1926, p. 416). After 1914 there has been only a small amount of prospecting on the property. It was last worked by E. W. Morey of Grizzly Flat during the period of 1939-41.

The deposit consists of a belt of nearly parallel quartz veins in a contact zone between granodiorite on the west and mica schist on the east. The belt is 300 feet wide and strikes N. 13° E., the three main veins in the belt strike from 2° to 10° east of the strike of the belt in which they lie. There are numerous spurs and lesser veins parallel to the principal veins. The quartz bodies of the veins are lenticular (Tucker, 1919, p. 292).

The ore shoots consist of lenticular bodies of banded quartz containing free gold, pyrite, galena, and sphalerite, and some chalcopyrite. The grade of the ore mined during the later operations is unknown, but between 1881 and 1887 it averaged $14 per ton (Logan, 1926, p. 416).

Most of the ore mined has been from the Earle vein on which most of the development work has been done (Logan, 1938, p. 241). The vein is developed by a 1,065-foot shaft with levels at 100-foot intervals. Most of the development was north of this shaft, and much of the output was from above the 850-foot depth. Drifts on the various levels range from 300 to 1,300 feet in length. There are more than 9,000 feet of drifts. Also there are two other shafts 300 to 600 feet deep. The ore was treated in a 10-stamp mill that burned down prior to 1926 (Logan, 1926, p. 417).

Nashville (Havilah, Tennessee-Nashville) Mine. Location: sec. 2, T. 8 N., R. 10 E., M. D., on the Mother Lode at Nashville. Ownership: Montezuma-Apex Mining Company, c/o National Tunnel and Mines Company, 818 Kearns Building, Salt Lake City, Utah.

The Nashville gold mine was worked first in 1851 and was credited with an output of $150,000 from shallow workings (Logan, 1934, p. 27). Much development work was done during the period of 1868-71 and again around 1880. A 20-stamp mill was erected on the property in 1894. The mine was active again from 1903 to 1906. The Montezuma-Apex Mining Company operated the mine from 1934 to 1936, and the ore was treated at the Montezuma mill. The mine has had a total output valued at about $400,000 (Logan, 1938, p. 233).

The vein, ranging from 5 to 20 feet in width, is in Mariposa slate. It strikes N. 10° E. and dips 60° SE. The ore was free milling containing 2 percent pyrite (Tucker, 1919, p. 292). Some of the ore produced during the 1930's averaged $5 per ton (Logan, 1938, p. 233).

The mine is developed by a 1200-foot inclined shaft with levels at each 100 feet. It is connected with the Montezuma mine to the north on the 1200-foot level. The last work done in the mine was on the 200-foot level south of the shaft and on the 1000-foot level north of the shaft where an ore shoot 80 feet long and 6 to 15 feet thick was mined (Logan, 1938, p. 233).

Placerville Gold Mining Company. Location: portions of secs. 6, 7, 17, 18, and 20, T. 10 N., R. 11 E., M. D., and sec. 36, T. 11 N., R. 10 E., M. D., extending from 1 mile south of the South Fork of the American River south through the Placerville city limits to Webber Creek, a distance of 4 miles. Ownership: Placerville Gold Mining Company, Box 191, Placerville, L. F. S. Holland, manager.

This concern owns a number of gold mines, both lode and placer, on the Mother Lode gold belt in and around Placerville. During the early days of the gold rush, these mines were the source of large amounts of gold. The present company was incorporated in 1911 and is a successor to the Placerville Gold Quartz Company, Ltd., an English concern that was incorporated originally in 1878. The best-known property of the group is the Pacific Quartz mine. Other notable mines of the group include the Epley Consolidated and True Consolidated.

The Pacific Quartz mine in the south portion of Placerville was operated from 1852-89, and again during 1914-15 (Logan, 1934, p. 35). Its total recorded production is $1,486,000 (Bowen and Crippen, 1948, p. 68). The Pacific vein is in a zone of talc and mariposite in Mariposa slate on the west side of the Mother Lode. Serpentine bodies are nearby. The vein strikes N. 25° W. and dips 70° NE. A number of ore shoots several hundred feet long and as wide as 12 feet were developed. The ore, which yielded $6 to $18 per ton in gold, contains appreciable amounts of arsenopyrite and silver. The mine is developed by a 700-foot shaft and 1,365-foot winze sunk from the 700-foot level. The ore was treated in a 20-stamp mill.

A consolidation of the Rose, Chester, Ida, Oregon, and Oregon Extension claims within the Placerville city limits was operated up until around 1888 (Irelan, 1888, p. 182). These claims were located at various times between 1865 and 1880. Gold-bearing quartz veins with arsenopyrite and galena in slate were developed by a 250-foot adit and a 225-foot inclined shaft. The ore was treated in a 10-stamp mill.

Just north of Placerville in Big Canyon is the True Consolidated mine, which includes the Young Harmon, Old Harmon, Halleck, and Berry claims. During the 1880's the property was operated by the True Consolidated Mining and Milling Company (Irelan, 1888, p. 180). These claims passed into the hands of the Placerville Gold Mining Company in 1893 (Logan, 1934, p. 26). The ore was treated in a 10-stamp mill. There are two northwest-trending veins in slate on the Mother Lode. The east vein has a greenstone hanging wall. The east vein averages 4 feet in width; the west averages 15 feet (Crawford, 1894, p. 125). Six ore shoots were known. The mine is developed by a 1,400-foot south drift adit. Also there is a 560-foot shaft on the

Old Harmon claim. In 1931, a small amount of prospecting was done on this claim (Logan, 1934, p. 26).

The Van Hooker, Grass, Brown Bear, Cinnamon Bear, White Bear, and Eureka claims lie north of the True Consolidated mine on the Mother Lode and are also owned by this company. These were worked prior to 1888 (Irelan, 1888, p. 181) and are extensively developed by underground workings. From 1928 to 1931, the Van Hooker mine was operated, and an ore shoot 80 feet long was mined. The ore yielded $7.25 to $27 per ton (Logan, 1934, p. 26). This mine is developed by a 1,200-foot drift adit and a winze. The ore was treated in a 10-stamp mill.

South of Placerville between Chili Ravine and Webber Creek is the Epley Consolidated mine, which was active up to 1888. This property consists of the Epley, Faraday, Henrietta, and Mammoth claims, which were located in 1867 (Irelan, 1888, p. 186). The vein in these properties strikes northwest, dips 65° NE., and averages 6 feet in width. Country rock is Mariposa slate. Two ore shoots, 125 and 150 feet long, were worked. The mine is developed by an adit and two shafts. The ore was treated by amalgamation, and a sulfide concentrate was sent to a chlorination plant.

Pyramid (Gold Reserve) Mine. Location: secs. 12 and 13, T. 10 N., R. 9 E., M. D., 4 miles due north of Shingle Springs and 2 miles southeast of Deer Valley. Ownership: Rhoads Grimshaw, Auburn.

The Pyramid gold mine was active during the 1890's, and the ore was treated in a five-stamp mill (Crawford, 1896, p. 154). An ore shoot over 500 feet long was developed. At this time the mine was worked through two 500-foot drift adits and a 50-foot shaft. After lying idle for many years, the mine was reopened in 1933 (Logan, 1935, p. 23). It was operated for the following 6 years by several concerns. The value of the total output of the mine is approximately $1,000,000 (Rhoads Grimshaw, personal communication, 1956).

This deposit is in the West Gold Belt. Country rock is amphibolite schist, lying between gabbro-diorite on the west and a band of serpentine on the east. Ankerite and mariposite are present in the wall rock. The main quartz vein, which ranges from a few to as much as 20 feet in width, strikes northwest, and dips 40° to 60° NE. The gold is associated with pyrite and smaller amounts of galena, arsenopyrite, and chalcopyrite. The mine is developed by an 818-foot inclined shaft. The later production was chiefly from the 500-, 700-, and 800-foot levels.

From 1933 to 1937, the ore was treated in a cyanidation plant equipped with a mercuric generator in which the formation of mercuric cyanide hastened the cyanidation process (Logan, 1938, p. 245). After 1938, the ore was treated in a 10-stamp mill and concentrated by tabling.

Rosecranz (Rosecrans) Mine. Location: sec. 21, T. 12 N., R. 10 E., M. D., 1½ miles northwest of Garden Valley. Ownership: Arthur S. Morey, 91 Rico Way, San Francisco.

This gold mine originally was worked prior to 1888 (Irelan, 1888, p. 171). At that time, it was worked to an inclined depth of 200 feet and the ore was treated in a 10-stamp mill. Around 1888, about $21,000 was produced from ore that yielded $10 per ton (Logan, 1938, p. 248). Some work was done on the property between 1916 and 1918. In 1936, the mine was reopened by the Lode Development Company of Auburn and was active until 1939.

Native gold and pyrite occur with quartz in a vein that lies in a 250-foot belt of amphibolite schist enclosed in Mariposa slate. The quartz occurs in irregular bodies. The vein strikes north, dips west, and averages 3½ feet in width. Eighty percent of the gold is in the native state (Logan, 1938, p. 249).

The Lode Development Company deepened the old shaft to 350 feet. There are levels at 100, 130, 200, 250, and 350 feet. Open stopes were used. Ore shoots ranging from 125 to 150 feet in length were worked both north and south of the shaft. On the 100-foot level a 165-foot crosscut was extended east to the adjoining Taylor vein (Logan, 1938, p. 249).

In the last operations, the ore was treated in a 100-ton mill that was equipped with a Bendelari jig and a bank of five flotation cells. Thirty men worked at the mine and mill.

Shaw (Shan Tsz, Volo) Mine. Location: sec. 21, T. 10 N., R. 10 E., M. D., 2 miles north of El Dorado and 4 miles southwest of Placerville. Ownership: Evelyn R. Purser, 110 Bank Building, South San Francisco; leased by Volo Mining Company, 464 Main Street, Placerville, F. V. Phillips, president, Joseph Pickering, mill foreman.

This is one of the better-known gold mines of the West Belt in El Dorado County. For many years it was worked as an underground mine. However, recently all of the ore has been mined from an open pit. It was active during the 1880's (Irelan, 1888, p. 193) and again around 1915 (Tucker, 1919, p. 297). The Volo Mining Company leased the property originally in 1940 (F. V. Phillips, personal communication, 1953). During 1941 and 1942, some gold ore was mined and milled on an experimental basis. The mine was shut down in 1942, but copper ore from several properties in the county was treated at the mill, which is known as the Volo mill, in 1943-44. The mine was reopened in 1946 and operated almost continuously until 1953. The mill is being used at the present time to treat copper ore from the Copper Hill mine in Amador County (see Volo mill in Copper section).

Gold mineralization has taken place in a body of quartzitic schist that lies in slate and schist of the Calaveras group. The deposit often has been referred to as a quartzite dike or rhyolite dike, but according to Fairbanks, the Shaw deposit genetically occupies an intermediate position between the Big Canyon deposit to the south, a true replacement deposit, and the ordinary fissure quartz vein deposit (Fairbanks, 1894, p. 480). Pyrite, calcite, and talc are associated with the gold. The ore is low grade, containing $2 to $4 per ton (Joseph Pickering, personal communication, 1953). The deposit contains seams of secondary albite and quartz as well as a few thin basic dikes. Rich pockets of free gold have been found near the contact of the ore body and the surrounding country rock (Tucker, 1919, p. 297).

The ore body strikes N. 10° E., and dips 85° SE. It averages about 100 feet in width and has been worked for a distance of about 1,000 feet along the strike. Prior to 1915, the mine was worked by underground methods. It was developed by a 135-foot shaft, a 400-foot crosscut adit, a 300-foot south drift, and a 200-foot north drift. After 1940, the mine was worked in an open cut that now is about 1,000 feet long, 100 to 150 feet wide, and 20 to 50 feet deep. The ore was blasted from the pit faces, loaded with a power shovel, and trucked to the mill.

The ore was treated by amalgamation flotation, and cyanidation at the mill which has a capacity of 300 tons. Five men worked at the mine and mill.

Skipper (Esperanza) Mine. Location: sec. 7, T. 12 N., R. 10 E., half a mile east of Greenwood. Ownership: H. R. Swartz, Greenwood.

This unpatented mining claim, which was once known as the Esperanza mine, has been worked intermittently by Mr. Swartz since 1935. The deposit consists of gold-bearing meta-andesite which is highly weathered and sheared. There is also some fresh greenstone containing auriferous pyrite. The gold is finely disseminated through the greenstone.

The zone of gold mineralization is 60 feet long and 40 feet wide and has a nearly east trend, although the country rock trends north. It is developed by an open cut several hundred feet long and a 50-foot, north-dipping inclined shaft sunk in the open cut. There are numerous prospect holes and cuts on the property.

Sliger Mine. Location: sec. 36, T. 13 N., R. 9 E., M. D., 1 mile west of Spanish Dry Diggings. Ownership: Sliger Gold Mining Company, 3628 Fulton Street, San Francisco; H. W. Simpers, president.

The Sliger gold mine was worked originally in 1864, and during the 1870's the ore was treated in a five-stamp mill on the property (Logan, 1926, p. 418). During these early operations the mine was worked to a depth of about 300 feet, and the production totaled $225,000 (Logan, 1934, p. 38). The property was idle until 1922 when the Sliger Gold Mining Company was organized. The shaft was deepened, a 15-stamp mill was erected, and milling of ore began in 1929. In 1932, a new mill with a flotation unit was erected. The mine was operated until 1934 by the Sliger Gold Mining Company and from 1934 to 1937 by the Middle Fork Gold Mining Company. In 1937, the Mountain Copper Company leased the mine and did some exploration work (Logan, 1938, p. 250). From 1938 to 1942, the mine again was operated by the Middle Fork Mining Company. The mine has been idle since 1942. In 1953 most of the surface plant was sold. From 1932 to 1942, 309,000 tons of ore were mined from which $2,625,000 was recovered (H. W. Simpers, personal communication, 1955).

The deposit is in a fault zone between Mariposa slate on the footwall and a band of serpentine on the hanging wall. Country rock is amphibolite. The ore is composed of siliceous slate containing numerous quartz veinlets with free gold, fine disseminated pyrite, and smaller amounts of arsenopyrite. Ankerite is present. The ore zone, which averages 30 feet in width, strikes north and dips 63° E. The ore shoots are lensoid in shape. However, they do not have definite walls but merge into lower-grade rock. It is believed that the gold-bearing solutions rose along several favorable bands in the slate to the fault zone, where they spread out to form the ore shoots (Logan, 1938, p. 250).

About 40 percent of the gold is free, as high as 925 in fineness, and about 60 percent is contained in sulfides (H. W. Simpers, personal communication, 1955). The tenor of the ore remained virtually unchanged from the 300-foot level down to the 2,000-foot level. The mine is developed by a 2,000-foot inclined shaft. Ore was mined in open stopes that later were filled with mill tailings.

At the mill the ore was treated by two-stage crushing and then sent to ball mills. From the mills, the pulp went to a Diester table, and table tailings were treated by flotation in six rougher and then two cleaner cells. During the last years of operation, an average of 150 tons of ore per day were mined (H. W. Simpers, personal communication, 1955).

Stuckslager Mine. Location: sec. 24, T. 11 N., R. 9 E., M. D., 1 mile southwest of Lotus. Ownership: Beryl E. McKenney, 31 Lake Vista Avenue, Daly City 25.

This gold mine was worked originally by the Stuckslager family during the 1860's. The property was purchased during the 1880's by the McKenney family who have operated it intermittently ever since (Mrs. E. J. McKenney, personal communication, 1955). From 1935 to 1942, the mine was worked by D. J. McKenney of Sacramento. At the present time E. J. McKenney Jr. is intermittently sinking a shaft on the hill above the adit portal.

This deposit is noted for the occurrence of roscoelite, a vanadium mica. Roscoelite is a very rare mineral found in few other places in the United States (Bowen and Crippen, 1948, p. 68). Native gold occurs in pockets with greenish or clove-brown scales of roscoelite in a quartz vein. The main vein strikes northwest, dips southwest, and ranges from a seam to 2 or more feet in width. Also present are a number of thin quartz stringers. Country rock is greenstone and slate lying between serpentine on the west and granodiorite on the east. The mine is developed by a 500-foot drift adit and several shallow shafts. During the 1930's, the ore was treated in a two-stamp mill. The shaft now being sunk is about 50 feet deep.

Sugar Loaf Mine. Location: secs. 1 and 12, T. 8 N., R. 9 E., M. D., 2½ miles northeast of Latrobe. Ownership: Sugar Loaf Mining Company, Route 1, Box 57, Shingle Springs.

This is a pocket gold mine of the West Belt. It first was worked by open cuts during the early days of the gold rush. It was active again during the 1880's. The mine was prospected during the early 1920's. During the middle 1930's a 175-foot shaft was sunk, and some high-grade ore was mined (J. H. Wren, personal communication, 1955). Since 1954, the mine has been operated intermittently by the Butler Mining and Development Company of Sacramento, and some high-grade ore has been shipped to the smelter.

Native gold associated with varying amounts of pyrite and galena occur in a quartz vein averaging 5 feet in width. The vein strikes north and dips 75° W. The footwall consists of slate; the hanging wall is talcose serpentine. Associated with the vein on the footwall side are several dikes of medium-grained diorite. The mine is developed by a 175-foot inclined shaft with levels at 100, 130, and 175 feet. High-grade ore was found recently in the vein just below the 100-foot level. Three men work intermittently at the mine.

Taylor (Idlewild) Mine. Location: secs. 21 and 30, T. 12 N., R. 10 E., M. D., on the Mother Lode 2 miles northwest of Garden Valley. Ownership: W. N. Guth, 2024 North New England Avenue, Chicago, Illinois.

The Taylor gold mine originally was worked in 1865 (Logan, 1934, p. 41). It was active again from the late 1880's to about 1902 (Logan, 1923a, p. 210). Some work was done on the property during the period of 1939-41 by the Lode Development Company of Auburn. The estimated total output of the mine is valued at about $1,000,000 (Logan, 1934, p. 42).

A vein about 2 feet wide at the surface, but increasing in width to an average of 14 feet at depth, lies between a Mariposa slate hanging wall and a hard greenstone footwall. The vein strikes northwest and dips 50° NE. There is a considerable amount of gouge in the hanging wall. The gold, which was finely divided, was in ribbon rock, the best ore being near the hanging wall. The grade of the ore ranged from $4 to $8 per ton (Logan, 1934, p. 42). The mine is developed by a 1,225-foot inclined shaft with levels every 100 feet. Because of heavy ground, stopes were filled with waste rock. The ore was treated in a 40-stamp mill, and the concentrates were cyanided.

Union (Springfield) Mine. Location: sec. 12, T. 9 N., R. 10 E., M. D., 2 miles southeast of El Dorado on the Mother Lode. Ownership: El Dorado Mining Company, P. O. Box 1724, Spokane 7, Washington.

The Union mine is considered to have been the largest source of lode gold in El Dorado County. However, because very few production figures have been made available (Logan, 1934, p. 42), the total output of the mine is unknown. The estimated value of the total output has ranged from $2,700,000 (Bowen and Crippen, 1948, p. 66) to as much as $5,000,000 (Tucker, 1919, p. 299).

In the early 1850's, rich surface outcrops of the area were worked, and soon after a shaft was sunk. The Union mine and the Church mine, later worked separately, were consolidated and produced more than $600,000 prior to 1868 (Logan, 1934, p. 42). The Union mine was worked again from 1871 to 1886, and the ore was treated in a 15-stamp mill. From 1896 to 1909, it was operated by the Union Gold Mining Company, which enlarged the mill to 20 stamps. Some prospecting was done on the property during 1914-15. In 1934, the mine was reopened by the Gold Fields American Development Company (Logan, 1938, p. 252). The shaft was deepened to 2,000 feet and the lower workings were rehabilitated. During 1936-37, the mine was operated by the Montezuma-Apex Mining Company and the ore was trucked to the Montezuma Apex mill at Nashville. Between 1937 and 1940, mining operation was sporadic and inconsequential. The mine has been idle since 1940.

A number of veins that strike north-northeast and dip 60° to 79° E. are in Mariposa slate. The principal veins are the Poundstone (or East Gouge), which had the greatest production, the McCosmic vein about 200 feet to the west, and the Klondyke vein, which was developed north of the main shaft. These veins range from 5 to 10 feet in width. A series of lesser veins lie to the west of the main veins. Ore from the

Poundstone vein yielded $8 per ton; the ore from the McCosmic vein yielded up to $25 per ton (Logan, 1938, p. 253). Ore recovered from shallow workings during the early days often was considerably richer.

The mine is developed by the 2,000-foot vertical main (Springfield) shaft which cuts the Poundstone vein at 1,200 feet and the McCosmic vein at about 1,540 feet. About 750 feet north is the 900-foot Clement shaft and 200 feet beyond is the 500-foot Klondyke shaft. Also there are several crosscut adits driven to the west, one 700 feet long near the Springfield shaft and another to the north near the Klondyke shaft about 600 feet long.

Vandalia Mine. Location: sec. 19, T. 9 N., R. 10 E., M. D., 4 miles south of Shingle Springs on the west side of Big Canyon. Ownership: G. L. Tripp, Route 1, Box 5, Shingle Springs.

This gold mine was worked originally in 1885 and was again active in 1888. The ore was treated in a five-stamp mill (Irelan, 1888, p. 172). It was idle during the 1890's, but around 1900, a cyanidation plant, which treated accumulated tailings as well as ore from the mine itself, was erected (Storms, 1900, p. 97). A small amount of work was done on the property in 1926 and 1928. During 1936-37, the Page Consolidated Mining Company prospected the mine and erected a 150-ton mill and cyanidation plant. However, little gold was produced (Logan, 1938, p. 254).

The deposit consists of bodies of fine-grained silicified schist containing disseminated auriferous pyrite. Country rock is amphibolite schist and quartz porphyry. The oxidized zone extended to a depth of about 100 feet. The ore bodies were over 80 feet wide, as much as 300 feet long, and commonly cut the chistosity of the enclosing rocks (Storms, 1900, p. 97). The mine was developed by several drift adits and open cuts.

Veerkamp (Gold Coin) Mine. Location: sec. 33, T. 12 N., R. 10 E., M. D., 1 mile west of Garden Valley on the Mother Lode. Ownership: Ray A. Veerkamp, Garden Valley.

A small amount of shallow prospecting was done on this gold property in the early days (Logan, 1934, p. 37). In 1933, some ore was mined from an open cut that was treated at the Beebe mill, and an adit was driven. From 1935 to around 1940, the property was operated by the Gold Company, Ltd., a Canadian concern. There was a small amount of work done in the mine again in 1950.

Several quartz veins as well as a number of quartz veinlets occur in highly weathered schist and slate. A large low-grade vein strikes N. 25° W. and intersects a smaller but higher-grade vein that strikes N. 15° E. A diabase dike lies just to the east. The ore contained about $12 per ton; some of the country rock enclosing the quartz veinlets contained up to $4 per ton (Logan, 1938, p. 247). Several pockets of high-grade ore were mined during the 1930's.

The mine is developed by a 180-foot shaft with levels at 60 and 97 feet. There are 1,200 feet of drifts on the 60-foot level and about 1,000 feet on the 97-foot level. Also there are several adits and a number of open cuts. Various methods of treating the ore were tried in a mill on the property, including flotation and cyanidation.

Zantgraf (Montauk Consolidated, Zentgraf) Mine. Location: sec. 16, T. 11 N., R. 8 E., M. D., 1 mile south of Rattlesnake Bridge on the east side of the American River, 6 miles southwest of Pilot Hill. Ownership: United States of America (land withdrawn for dam site).

The Zantgraf gold mine first was worked in 1880 (Logan, 1938, p. 255) and in 1888 a 10-stamp mill was in operation (Irelan, 1888, p. 201). It was active during the 1890's, and the mill was enlarged to 20 stamps (Crawford, 1894, p. 162). Between 1898 and 1901 it was operated by the Montauk Consolidated Mining Company. The total output for the mine up to 1901 was valued at about $1,000,000 (Logan, 1938, p. 256). The property was idle until 1924 when a small amount of prospecting was done just north of the mine. From 1933 to 1938 and again in 1941, W. B. Longan prospected the property and some gold was produced. Several shallow shafts were sunk and a considerable amount of drifting was done. The mine has been idle since.

There are several nearly parallel veins in granodiorite and amphibolite. Amphibolite lies to the east. The veins strike northwest, dip 38° to 50° SW., and are accompanied by diorite dikes. The mine workings are largely in granodiorite. Nearly all ore that was mined was from the main or Zantgraf vein, which ranges from 2 to 6 feet in width. The ore contained free gold with associated auriferous pyrite and galena. The values of the ore ranged from $2 to as much as $100 per ton, but averaged between $7 and $8 per ton (Logan, 1938, p. 256).

The mine is developed by a 1,130-foot inclined shaft with levels at every 100 feet. There is a 500-foot crosscut adit that joins the shaft on the 300-foot level. An ore shoot was stoped from the 300-foot level to the surface for a distance of 900 feet. Another ore shoot 600 feet long was developed in the lower levels. There is also a 200-foot shaft 900 feet northwest of the main shaft with levels at 80 and 180 feet, and a 190-foot shaft on the Montauk vein, both of which were sunk in the 1930's.

The ore was originally treated in a stamp mill. During the 1930's a 50-ton Chilean mill was used; it was later replaced by a ball mill.

Placer Deposits

Placer gold deposits in El Dorado County have been worked by dredging, hydraulicking, and drift mining. Most dredging has been done with dragline dredges, although a few connected-bucket dredges were used at one time. Hydraulic mining consists of directing large jets of water under high pressure toward banks of gold-bearing gravels. The excavated gravels flow through strings of sluice boxes where the gold is recovered. Buried stream channels of Tertiary age have been developed by underground mines known as drift mines. Drifts and crosscuts are run along pay streaks in the old river channels. The excavated gravel is brought to the surface and sluiced or sent through a washing plant to recover the gold.

Placer gold deposits in El Dorado County range from Eocene to Recent in age. The gold in all of the placer deposits originated from veins in the granitic and metamorphic rocks of the Sierra Nevada. When those veins were subjected to prolonged erosion and weathering, the gold was released and became intermingled with other weather-resistant material in streams. It was then concentrated by the action of running water usually at or near the base of the stream deposits.

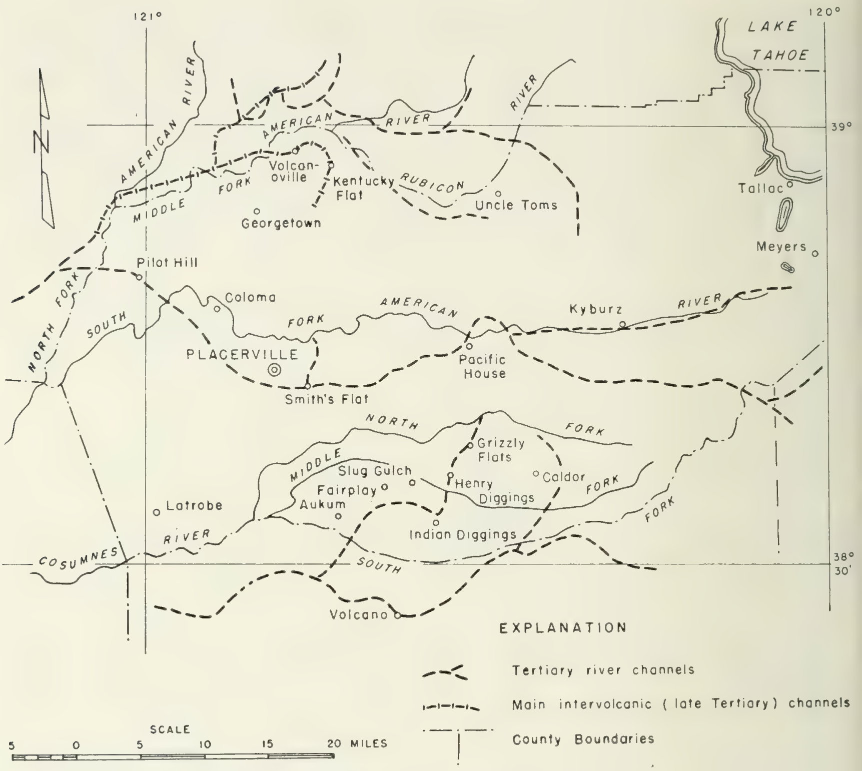

121°
120°
LAKE
TAHOE
39°
N
AMERICAN RIVER
MIDDLE FORK
AMERICAN RIVER
RIVER
RUBICON
Volcanoville
Kentucky Flat
Georgetown
Uncle Toms
Tallac
Meyers
Pilot Hill
NORTH FORK
SOUTH FORK
Coloma
AMERICAN RIVER
Kyburz
PLACERVILLE
Pacific House
Smith's Flat
NORTH FORK
MIDDLE FORK
Grizzly Flats
Slug Gulch
Fairplay
Aukum
Henry Diggings
Caldor
Latrobe
COSUMNES RIVER
SOUTH FORK
Indian Diggings
Volcano
38° 30'
EXPLANATION
Tertiary river channels
Main intervolcanic (late Tertiary) channels
County Boundaries
SCALE
5 0 5 10 15 20 MILES

FIGURE 21. Map of El Dorado County showing Tertiary river channels (after Lindgren 1911, and Jenkins 1932).

Associated with the gold in placer deposits are magnetite and other heavy resistant minerals such as ilmenite, garnet, rutile, zircon, and platinum-group metals. The most productive placer deposits in the county were in Tertiary channels in the Placerville area.

The present river and stream systems that developed in the Quaternary period swept away much of the Tertiary volcanic cover and cut new canyons in the bedrock. Some of the canyons are several thousand feet below the old surface. This tremendous amount of erosion and natural concentration of heavy materials resulted in accumulation of large quantities of gold in the present streams and their branches. These deposits range in size from those that are small but often rich in tributary creeks to the large dredging fields many square miles in extent that lie west of El Dorado County. Small rich surface deposits in tributary creeks were responsible for the very large amounts of gold produced during the first few years of the gold rush. During the 1930's there was considerable placer mining in El Dorado County along the American and Cosumnes Rivers and many of the creeks. At most of these operations, draglines and floating washing plants known as "doodlebugs" were used.

In Eocene times, the American and Mokelumne Rivers occupied different channels than they do now. Gold was concentrated in these ancient ancestral channels, some of it in rich deposits. Volcanism that began at or near the end of the Eocene epoch and continued into the Pliocene epoch buried these channels under great thicknesses of volcanic material. Several times during the period of volcanism, the rivers were forced into new channels, which now are known as "intervolcanic channels." The intervolcanic channels generally are leaner in gold than the early Tertiary channels. Portions of the ancient channels were preserved by the thick cover of volcanic rocks and are exposed on the sides of the present stream canyons.

Detailed descriptions of the Tertiary channel deposits as well as a discussion of their geology are contained in U. S. Geological Survey Professional Paper 73 (Lindgren, 1911). Information also can be found in *Auriferous gravels of the Sierra Nevada* (Whitney, 1880), California Mining Bureau Bulletin 92 (Haley, 1923), Geologic map of the northern Sierra Nevada (Jenkins, 1932), *California's gold-bearing Tertiary channels* (Jenkins and Wright, 1934), and California Division of Mines Bulletin 135 (Averill, 1946).

The most productive Tertiary channel deposits in El Dorado County were in the Placerville area, east and northeast of Georgetown, and in the Grizzly Flat-Fairplay-Indian Diggings region. These areas are described separately in this report, and the individual mines are described in the tabulated list under *Placer gold*.

Georgetown Area. An intervolcanic channel of the Middle Fork of the American River flowed north from Tipton Hill, 5 miles northeast of Georgetown, to the old mining camp of Kentucky Flat. At Kentucky Flat the main or "white" channel, which is 350 to 500 feet wide, is known for the abundance of large quartz boulders and the coarseness of the gold. Several other intervolcanic channels exist locally that differ in direction from the main channel (Lindgren, 1911, p. 168). Probably the best-known operation in the Kentucky Flat area was that of the Two Channel Mining Company, which operated extensive drift and hydraulic mines for several miles along the channel during the 1890's (Crawford, 1896, p. 160). The principal sources of gold were the Kenna, Kentucky Flat, Morris, and Tiedeman mines. Gravel at the Kenna mine was well cemented and was treated in a 10-stamp mill.

From Kentucky Flat, the channel turned west and flowed through Volcanoville. Considerable amounts of gold were produced from drift and hydraulic mines in the Volcanoville area. In places, such as at the Buckeye Hill mine on Buckeye Point, the channel was as much as 1000 feet wide (Crawford, 1894, p. 105). This mine was active during the 1890's and again during the 1930's. Other notable sources of gold in the area included the Channel Bend, Gray Eagle Cliff, and Rubicon mines. Gold also was mined from isolated patches of Tertiary gravel capping several peaks southwest of Volcanoville and north of Georgetown. These include Bottle Hill, Cement Hill, and Jones Hill. This channel continued on into Placer County southwest of Foresthill. Two other branches of the Tertiary Middle Fork lie to the east: one extends west from near Uncle Tom's and northwest along Peavine Point east of Kentucky Flat; the other extends in a north-northwest direction east of Uncle Tom's. Little gold has been mined from these two channels.

Mokelumne River Deposits. A channel of the Tertiary Mokelumne River flowed south from just south of Baltic Peak to Grizzly Flat. At

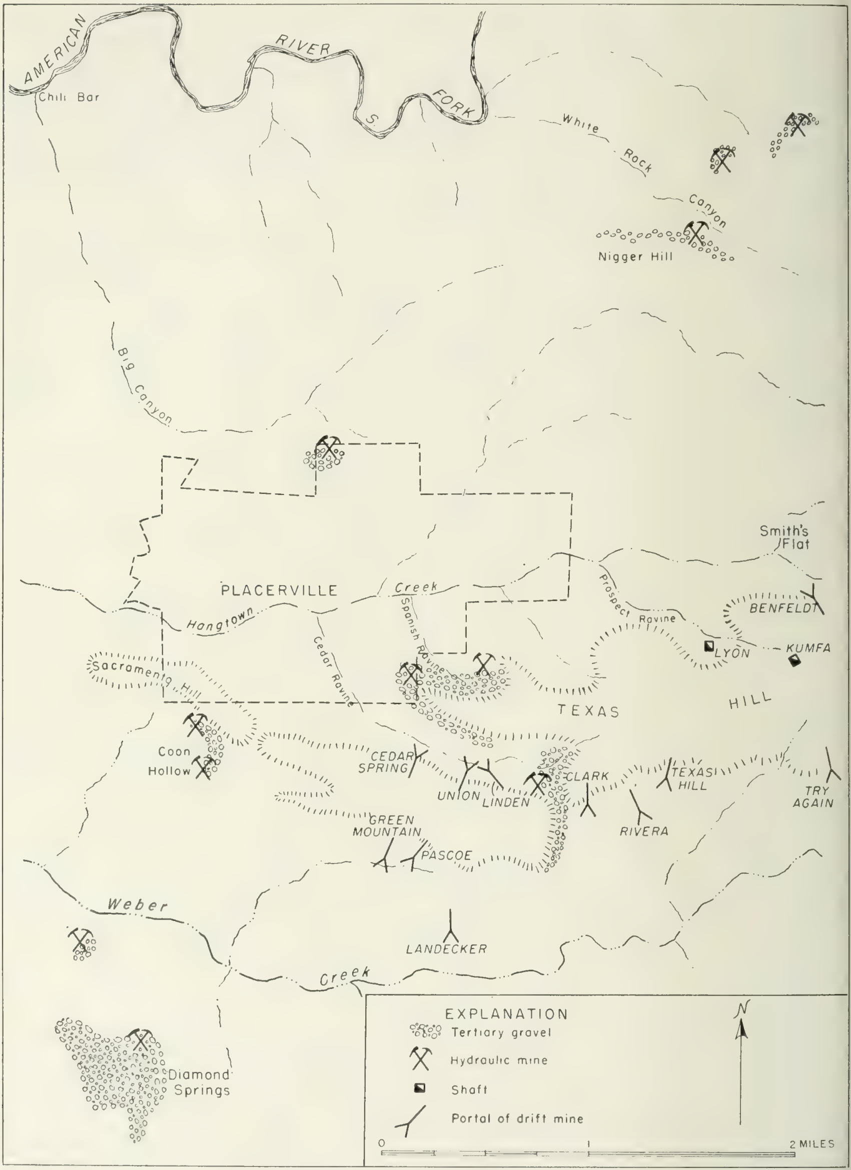

AMERICAN RIVER
S. FORK
Chili Bar
White Rock Canyon
Nigger Hill
Big Canyon
Smith's Flat
PLACERVILLE
Hangtown Creek
Spanish Rovine
Cedar Rovine
Prospect Rovine
BENFELDT
LYON
KUMFA
Sacramento Hill
TEXAS HILL
Coon Hollow
CEDAR SPRING
UNION
LINDEN
CLARK
TEXAS HILL
TRY AGAIN
RIVERA
GREEN MOUNTAIN
PASCOE
Weber Creek
LANDECKER
Diamond Springs
EXPLANATION
Tertiary gravel
Hydraulic mine
Shaft
Portal of drift mine
N
0
1
2 MILES

FIGURE 22. Sketch map of Placerville area, showing locations of former placer mines and Tertiary gravel deposits.

Grizzly Flat, gold-bearing gravels underlie tuffaceous andesite and rest on granitic bedrock. The gravels are thin and the channel narrow (Lindgren, 1911, p. 180), but substantial quantities of gold were produced from drift and hydraulic mines in this district in the past. The Grizzly Flat mine, which was active during the 1880's, 1890's, and again in 1918, was an important source of gold.

This channel appears again at the old mining camp of Henry Diggings, a few miles to the southwest. The gravels here were rich (Lindgren, 1911, p. 180). Notable sources of gold in this area were the Armstrong, Carrie Hale, Irish Slide, Last Chance, and Payne drift mines. Continuing south, the main channel flowed just west of Brownsville, another old mining camp one mile south of Omo Ranch, and then southwest to a point about a mile north of Indian Diggings.

Although Indian Diggings is not on the main channel, gravel deposits here were extremely productive. Bedrock is a wide belt of limestone which contained numerous rich potholes. The Hayward mine, which is a consolidation of several drift and hydraulic mines, was a major source of gold in the district. As late as the early 1900's, the annual gold output for the district was $7,000 to $10,000 (Lindgren, 1911, p. 181). During the 1920's the Jinkerson drift mine was active (Logan, 1926, p. 439), and the Ball drift mine was worked in the 1930's (Logan, 1938, p. 217).

Auriferous gravels are present in the Fairplay area, although they too are not part of the main channel. A channel that extended from Slug Gulch southeast to Fairplay was mined by hydraulicking for many years. The California Mohawk Mining Company operated properties that extended several miles along this channel (Tucker, 1919, p. 301). Recently some radioactive material was discovered at Slug Gulch (see section on Radioactive Minerals).

There was another south-flowing channel of the Tertiary Mokelumne River east of Caldor. Some gold was mined from isolated gravel deposits along this channel by hydraulicking (Lindgren, 1911, p. 183).

Placerville Area. The most productive Tertiary channel deposits in the county were in the Placerville area. This area includes the deposits at Coon Hollow, Diamond Springs, Smith's Flat, Texas Hill, and White Rock. The value of the total gold output for the district has been estimated to be about $25,000,000 (Haley, 1923, p. 144). The Tertiary South Fork of the American River entered the area from Newtown. There are numerous tributaries in the area, some of which have yielded large amounts of gold. Nearly all are overlain by rhyolite tuff; bedrock is Mariposa slate, Calaveras metasediments, and granodiorite.

The best known tributary is the Deep Blue Lead which has been traced south from White Rock Canyon to Smith's Flat and southwest to Cedar Ravine. This tributary follows approximately a slate-granodiorite contact for several miles and is believed to have derived much of its gold from many small veins in the contact zone. It was mined extensively between the late 1860's and the 1890's. The gravels at White Rock yielded $5,000,000 while the Lyons mine just south of Smith's Flat yielded $1,400,000 (Lindgren, 1911, p. 172). The latest work of any extent in the Smith's Flat area was at the Hook-and-Ladder mine which was operated almost continuously from 1918 to 1932 (Averill, 1946, p. 255).

Rich gravels were mined in the area between Coon Hollow and Texas Hill. Drifting was done at Coon Hollow from 1852 to 1861, and the hill was hydraulicked from 1861 to 1871. This area was the source of about $10,000,000 (Lindgren, 1911, p. 172). The Excelsior claim in Coon Hollow yielded $5,000,000 from an area 20 acres in extent (Whitney, 1880, p. 119). The gravels contained as much as $5 per yard. At present accumulated tailings in Coon Hollow are being mined for sand and gravel by the Harms Construction Company (see Stone section).

The Green Mountain and Cedar Spring channels lying east of Coon Hollow were extensively mined by drifting. Gravels at Spanish Hill were the source of gold valued at $6,000,000 (Lindgren, 1911, p. 172). The Deep Blue Lead, which continued in a southwest direction from Smith's Flat was developed by the Linden and Landecker drift mines. Other productive mines in this portion of the area included the Clark, Ditch Company, Rivera, Texas Hill, and Try Again mines.

Gold Dredging. There have been a large number of gold dredging operations in El Dorado County. The majority of these were the dragline dredges or ''doodlebugs'' which were active during the 1930's and 1940's. At present, there is little gold dredging in the county.

Among the earlier (1914-18) dredging operations in El Dorado County were those of El Dorado and Placer Counties Gold Mining and Power Company, which operated a floating dredge with 3½-cubic-foot buckets on the Middle Fork of the American River near Poverty Bar, and the Pacific Gold Dredging Company, which operated a floating dredge with 7½-cubic-foot buckets at Mammoth Bar (Logan, 1918, p. 29). A dragline dredge was operated at the Jumbo Placer mine on Carson Creek 1 mile west of Clarksville in 1923 (Logan, 1923b, p. 142). In this operation, gravels were excavated by a dragline and delivered to a hopper which fed a sluice box.

During the period of 1924-25, the Boles placer claim on the American River upstream from Rattlesnake Bridge was prospected by a combined diving and pumping operation (Logan, 1926, p. 428). A diver at the bottom of the river directed the nozzle from a barge-mounted suction pump that discharged into sluice boxes. Large boulders were removed by a scoop lowered from an overhead cable spanning the river.

Between 1933 and 1941, dragline dredging methods and equipment were greatly improved. This, coupled with a rise in the price of gold in 1934, caused a great increase in the production of placer gold in El Dorado County during this period. Also, a lower capital outlay and portability of a dragline dredge made it possible to work many deposits that were too small to justify the construction of a connected-bucket dredge. Many of the creeks and gravel deposits in western and central El Dorado County were dredged by these outfits during the 1930's.

Dragline dredges or ''doodlebugs'' consist essentially of two parts, a dragline excavator and a washing plant. Draglines used in this type of work are equipped with buckets ranging from 1 to 3 cubic yards in capacity. Floating washing plants are mounted on a barge and consist of a hopper into which the gravel is delivered, a trommel, a belt conveyor to stack the coarse tailing, and banks of riffles. Usually a tractor with a scraper is used to clear the way ahead for the dragline. Draglines are most successful where the gravel is not much more than 20 feet deep and not too compact or well cemented. Published production figures for El Dorado County show recoveries have ranged from 15 to 30 cents per cubic yard.

A few non-floating washing plants have been employed. These washing plants are mounted on tractor treads and usually are self-propelled. Also, a few suction dredges have been employed. These consist of a barge-mounted pump with pipe, a digging nozzle, and a washing plant mounted on the barge.

According to U. S. Bureau of Mines records, at least 33 dredges have been active in the county since 1938. Most of these have been dragline dredges with floating washing plants. All known dredging operations are in the tabulated list in the back of this report (see placer gold in tabulated list).

The following are some of the better-known gold-dredging operations of recent years in El Dorado County:

Big Canyon Dredging Company of Fresno operated a dragline with a 3-cubic-yard bucket in the Deer Creek area, near Shingle Springs, from 1938 to 1943. As much as half a million yards of gravel per year was handled (Averill, 1946, p. 255); recoveries averaged about 16 cents per yard.

El Dredging Corporation of Greenwood operated a dragline dredge with a 1½-cubic-yard bucket in the Coloma and Greenwood areas in 1940-41, near Georgetown in 1946-47, and near Camino in 1948.

General Dredging Corporation of Natoma operated a 1½-cubic-yard dragline dredge and a second 2-cubic-yard dragline dredge in the Coloma area from 1939 to 1942 and near Shingle Springs in 1941.

Greenhorn Dredging Company of Auburn operated a 2-cubic-yard dragline dredge on the Middle Fork of the Cosumnes River near Youngs during 1940-42 and again in 1947.

Lord and Bishop of Sacramento operated a 3-cubic-yard dragline dredge and Bodinson floating washing plant on Greenwood and Carson Creeks in 1949 and 1950.

The River Pine Mining Company, Ltd., of San Francisco operated a 2-cubic-yard dragline and floating washing plant on the Middle and North Forks of the Cosumnes River during 1941-42, 1946, and 1949-50.

Seam Deposits

El Dorado County's "seam diggings" or seam gold deposits are in the north portion of the Mother Lode belt north of Placerville. They are found in Mariposa slate as well as in amphibolite and chlorite schist. The gold is in narrow quartz veinlets in the country rock in definite zones. These zones, which are as much as several hundred feet wide, contain quartz veinlets in several systems which have definite dips and strikes. The richest portions of seam deposits are for the most part near the intersections of two or more systems of veinlets, or where one system intersects a larger quartz vein (Logan, 1934, p. 43).

The surface portions of the seam deposits have been subjected to long-continued weathering. As rock disintegration by mechanical breakdown and chemical weathering progressed, the softer and more soluble portions of the rock were carried away by erosion, leaving the quartz veinlets and gold. As this process continued, the surface portions of these deposits became enriched. The name "residual placer" has been applied to this type of deposit (Jenkins, 1935, p. 158).

The soft, weathered, upper portions of seam deposits first were mined by hydraulicking and sluicing. After the residual material had been removed, the hard, unweathered, mineralized portions of the deposits were encountered and mined as lode-gold deposits by conventional underground methods.

Seam deposits were worked extensively by hydraulicking during the 1860's and 1870's. Old records show the surface portions contained about $1 per cubic yard in gold (Logan, 1934, p. 44). The largest and most productive seam deposits were in the Georgetown, Spanish Dry Diggings, Greenwood, and Garden Valley areas. The seam mines at Georgia Slide northwest of Georgetown had the highest total gold output of the seam deposits.

Georgia Slide (Beattie, Blue Rock, Mulvey Point, Pacific, Parsons) Mine. Location: sec. 3, T. 12 N., R. 10 E., and secs. 34 and 35, T. 13 N., R. 10 E., M. D., 1½ miles north-northwest of Georgetown on the south side of Canyon Creek. Ownership: Kelsey Lumber Company, 515 Main Street, Placerville.

The best-known and largest seam gold deposit in the county, the Georgia Slide mine, includes the Blue Rock, Beattie, Mulvey Point, Pacific, and Parsons claims. These claims originally were worked separately. The Beattie claim was mined by hydraulicking continuously from 1853 to 1895 and the Blue Rock and Pacific claims continuously from 1856 to 1895 (Logan, 1934, p. 46). After the cessation of hydraulic mining, small amounts of ore were treated in several stamp mills that had been erected on the property. In 1915, a 10-stamp mill was being operated to determine the gold content of the large amount of accumulated tailings (Knopf, 1929, p. 48). Later a number of lessees worked the quartz stringers in search of high-grade pockets.

As the value of the estimated total output of the seam mines is $3,000,000 (Knopf, 1929, p. 49), and about $3,500,000 was believed to have been taken from placer deposits in Oregon Canyon and Canyon Creek, which derived their gold from the seam deposits (Logan, 1934, p. 46), this deposit has been the source of at least $6,500,000 in gold. It is estimated that about 3,500,000 cubic yards were removed from the immense open pit that now remains (Knopf, 1929, p. 49).

The deposit is a lenticular body of highly weathered green chloritic siliceous schist with some interbedded black slate. It strikes N. 5° W. and dips 80° E. The seams are gold- and pyrite-bearing quartz stringers ranging from less than an inch to a foot or more in thickness. The average stringer was 1 to 2 inches thick. Some of the gold mined from this deposit was beautifully crystallized. Some stringers swelled into lenses several feet thick. In some places albite and calcite are present in abundance. According to Preston, the material that was mined contained $2 to $3 per ton in gold (Preston, 1892, p. 203). There were five belts of schist in which the stringers were more abundant than elsewhere (Knopf, 1929, p. 40). The easternmost belt was 35 feet thick.

Originally the deposit was mined by hydraulicking. Later the banks were excavated by blasting, and the debris was hydraulicked into sluices. Whenever the quartz seams were encountered they were treated by hand mortaring (Crawford, 1894, p. 102). At present, there is a huge open pit about 1000 feet long and nearly 600 feet wide at the top. Water for hydraulicking was obtained from Canyon Creek, North Canyon, and Dark Canyon.

Hart Mine. Location: sec. 27, T. 12 N., R. 10 E., M. D., between Manhatten and Empire Creeks 1 mile north of Garden Valley. Ownership: Daniel Gellermann, 4524 Brand Way, Sacramento.

The Hart gold mine is in the seam belt just north of the split in the Mother Lode belt at Garden Valley. In the early days, the property was worked by hydraulic mining (Logan, 1934, p. 47). Later the deposit was prospected to determine the feasibility of erecting a mill. In 1930, a mill was erected (Logan, 1938, p. 233), and the property was worked intermittently until 1939.

This deposit is in the same belt of amphibolite schist that contains the Alpine and Black Oak gold mines. Four parallel systems of veins and stringers have been developed. The average gold recovery of ore mined in this property for the 4 years prior to 1938 was $5 per ton (Logan, 1938, p. 233).

The mine is developed by an open pit 175 feet long, 50 feet wide, and 40 feet deep, two drift adits, and two shafts, 200 and 300 feet in depth. The ore was treated in an eight-stamp mill.

Iron

Iron ore is found in several localities in El Dorado County, but there has been no recorded production. At the Reliance deposit north of Bass Lake in the western portion of the county, there are two vein-like bodies of magnetite several feet thick in coarse-grained gabbro. At the Chaix prospect near Latrobe, there is a lens of magnetite and hematite with a considerable amount of silica.

Lead

Small amounts of lead have been produced nearly every year as a by-product of gold and copper mining in the county. The primary mineral galena (PbS) is the principal ore mineral. In El Dorado County, galena occasionally is a minor constituent of Mother Lode gold ores and foothill copper ores. In a few cases, galena is a major constituent of East Belt gold ores. At present most of the lead produced in the county is from the Hazel Creek gold mine, where considerable amounts of galena are present in the ore. The galena is recovered by selective flotation.

Manganese

Although there has been no recorded output of manganese ore in the county, several small deposits were prospected during World War I and again during World War II. The largest of these were the Alderson deposit 1½ miles south of Placerville, where manganese oxide in sandstone interbedded with Tertiary volcanic rocks crops out for a distance of 150 feet, and the David deposit west of Georgetown, where thin veins of manganese oxide are found in chert and quartzite. Other prospects include the Martinez and Mocettini deposits (see manganese section in tabulated list). Most of the manganese of the Sierra Nevada was originally deposited with silica as a silicate or as a carbonate. Manganese silicates (bementite and rhodenite) and carbonates (rhodochrosite) are the primary minerals which subsequently weather to black manganese oxides (pyrolusite and psilomelane).

Molybdenum

Small amounts of molybdenum minerals have been found in El Dorado County, but there has been no recorded production. At the Cosumnes copper mine, molybdenite (MoS_2) and powellite ($CaMoO_4$) occur in the tactite associated with bornite and chalcopyrite.

Nickel

Garnierite, an ore mineral of nickel in several places in the world, has been found in lateritic soils at the Pillikin chrome mine. Also it has been reported near Lotus (Murdoch and Webb, 1948, p. 155). However, nickel has not been produced in the county.

Garnierite, an amorphous hydrous magnesium nickel silicate, is found in rounded masses with smooth surfaces or as earthy fillings in veins or in cavities in zones containing silica veinlets in decomposed bedrock. Such deposits originated by residual concentration resulting from decay of ultrabasic rocks such as serpentine, under intense weathering conditions. Almost all ultrabasic rocks contain some nickel. However, only under proper conditions of weathering are these rocks decomposed and the nickel and some of the silica concentrated in the soil mantle. These soils are known as laterites and occur in the serpentine areas of El Dorado County. These are the most favorable areas in the county for nickel.

Platinum-Group Metals

Minor amounts of platinum and related metals have been recovered sporadically in El Dorado County as a by-product of placer-gold operations. Platinum-group metals are found as alloys in smooth thin flakes and small rounded nuggets in placer deposits. The proportion of these metals to gold is usually small. Platinum is believed to have been originally deposited by magmatic processes in basic and ultrabasic rocks. In placer mining it usually is recovered by jigging and panning the black sand concentrate after the gold has been removed.

Quicksilver

Some quicksilver was produced in El Dorado County in the 1860's at the Bernard cinnabar mine two miles west of Nashville (see tabulated list). The mine was prospected in 1903 and again in 1917, although there is no later record of production (Logan, 1926, p. 445). Traces of cinnabar also have been found in an area south of Shingle Springs (Logan, 1926, p. 445).

Radioactive Minerals

For the past several years there has been some prospecting for uranium in El Dorado County. A number of claims which have shown radioactivity have been located. One property has had some development work done. However, as yet no uranium ore has been mined.

Intermittent development work is being done on a prospect in the Slug Gulch area 3 miles due east of Fairplay on land owned by Clifford Smith of Somerset. This is near a hydraulic mine that was worked many years ago. Some radioactive material was found in highly weathered shear zones and in several small fissures in metamorphic and granitic rocks. Some of the soil in the area also is radioactive. It is not known if uranium is present. The area of radioactivity is several yards wide and about a quarter of a mile long. A number of shallow open cuts have been made with a bulldozer.

Claims for radioactive minerals have been located in the High Meadows area 5 miles southeast of Stateline and in an area several miles west of Silver Lake. Country rock in both these areas is granodiorite.

Silver

The recorded value of the output of silver in El Dorado County from 1880 to 1953 is $161,706. Virtually all of this was a by-product of gold and base-metal mining. Silver occurs alloyed with native gold in lode and placer deposits and with sulfide minerals in base-metal ores. At the present time, the Hazel Creek gold mine, the ore of which contain a high percentage of galena, accounts for much of the silver produced in the county.

Titanium

Small amounts of ilmenite, a titanium-bearing mineral, are found in the black sands in stream channels in El Dorado County. Ilmenite ($FeTiO_3$) is a heavy black resistant mineral that is related in origin to intrusive rocks—most commonly to basic rocks but in some cases to acidic rocks such as granite pegmatite.

Tungsten

Several thousand dollars worth of tungsten ore was mined from the Comeback Consolidated mine in 1932. However, there has been no other recorded output of tungsten ore in El Dorado County. In the past few years there has been a considerable amount of prospecting, and several prospects have been discovered. Early in 1956, the Sciaroni brothers were developing a prospect and treating small lots of ore in a pilot mill at Grizzly Flat.

Scheelite ($CaWO_4$) is found in contact metamorphic zones where calcareous rocks of the Calaveras group have been intruded by granitic rocks. The most common rock in which the scheelite occurs is tactite. Scheelite is most easily recognized by a light blue fluorescence under ultraviolet light. Sulfides, chiefly pyrite, often are associated with the scheelite.

Comeback Consolidated (Bear Creek) Mine. Location: sec. 4, T. 11 N., R. 11 E., M. D., 7 miles northeast of Placerville and 4 miles due east of Spanish Flat near the north bank of Rock Creek. Ownership: Ajax Consolidated Mines Company, c/o Bruce Thompson, First National Bank Building, Reno, Nevada.

This property has been the source of the total recorded output of tungsten ore in the county. The claims first were located in 1930 (Logan, 1938, p. 365). During 1931-32, between $3,000 and $4,000 worth of scheelite was produced from this property by sluicing (Averill, 1943, p. 318). The property was worked again in 1943 by H. G. Walker of Placerville, and some scheelite was produced by running dump material through a small jig. In the past few years the present owner has prospected the property.

The scheelite is in a calcite vein and in a fracture that intersects the calcite vein. Country rock is chlorite schist of the Calaveras group. The vein, which is 2 to 3 feet wide, strikes north-northwest and dips 50° to 60° W. Some of the scheelite occurs in masses or in coarse individual crystals. Small amounts of free gold are present. The deposit is developed by a 187-foot adit that was driven along the fracture for 100 feet and then north along the vein. Fifty feet above and below this adit an 80-foot and a 240-foot adit respectively have been driven.

Grizzly Flat Deposit. Location: sec. 32, T. 10 N., R. 13 E., and sec. 5, T. 9 N., R. 13 E., M. D., on Sturdevant Ridge 3 miles northwest of Grizzly Flat. Ownership: north portion by the Caldor Lumber Company, Diamond Springs; central portion by Horace Pierce, Sacramento, leased by E. L. Wilbur, North Sacramento; south portion, by Americo and Columbus Sciaroni, Grizzly Flat.

Scheelite was discovered in this area about 1950 (Columbus Sciaroni, personal communication, 1955). Early in 1956, the Sciaroni brothers were making a series of open cuts, and driving an adit in the south portion of the deposit. In the central portion of the deposit, E. L. Wilbur was removing the overburden by bulldozing, and samples were being taken.

Discontinuous bodies of scheelite-bearing rock occur in a northwest-trending zone of contact-metamorphic rock that is in metasediments of the Calaveras group. The zone is about 1 mile long and more than 600 feet wide. It consists of layers of garnet-epidote tactite, interbedded with quartz-mica schist, quartzite, and granite gneiss. A few small quartz veins are present. Disseminated scheelite occurs in the tactite and in the adjoining quartz-mica schist. Some scheelite was found in quartz veins near the south end of the deposit. The scheelite-bearing horizons range from 5 to 30 feet in width and are as much as several hundred feet in length. For the most part the scheelite is fine grained, although a few coarse crystals have been found. Several assays made of selected samples of scheelite-bearing tactite showed 1 to 2 percent WO_3 (Columbus Sciaroni, personal communication, 1955).

There has been no recorded production from this deposit. However, the Sciaroni brothers have been concentrating small amounts of ore in a small pilot mill and stockpiling the concentrates. The ore is crushed, fine ground, and sent through a Denver jig; the jig overflow is concentrated on a small Deister table. Concentrates are stockpiled.

Williams prospect. Location: sec. 1, T. 9 N., R. 11 E., M. D., 7 miles southeast of Placerville and 1 mile northeast of Buck's Bar. Ownership: Blanche Williams, Placerville; leased by F. T. Lee and J. Needham, Sacramento, California.

This tungsten prospect was discovered in 1954 and was in the development stage in early 1956. An open cut 20 feet long, 20 feet wide, and 15 feet high has been made on the south slope of a ridge. Several tons of ore were mined for milling tests. A number of analyses show that parts of the deposit contain from 1 to 2 percent WO_3 (F. T. Lee, personal communication, 1955).

Scheelite occurs in a northwest-trending body of garnet-epidote tactite that pinches out near the surface and widens at depth. The greatest width of exposed tactite is about 12 feet. The scheelite is in thin parallel streaks near the center of the tactite body. Quartz, calcite, and minor amounts of pyrite are present. Country rock is quartzite and mica schist of the Calaveras group. A large body of granodiorite lies to the south.

Zinc

Minor amounts of zinc are produced intermittently as a by-product of copper and gold mining. Sphalerite (ZnS), the principal zinc mineral of the Sierra Nevada, is a minor constituent of some Mother Lode and East Belt gold ores. In some portions of the foothill copper belt, however, especially to the south in Calaveras County, zinc is nearly as abundant as copper. Sphalerite is concentrated by selective flotation.

Nonmetallic Minerals

Asbestos

A total output of 142 tons of asbestos was recorded for El Dorado County during the period 1904-06. There is no record of any asbestos having been mined after 1906. Part of this asbestos was from the Contraband copper mine near Georgetown (Aubury, 1906, p. 262). Asbestos also is found at the French Hill gold mine near Spanish Dry Diggings, although there is no record of its output (Logan, 1938, p. 207).

Chrysotile and amphibole asbestos usually are found in or near massive serpentine bodies, in veins or veinlets in parallel or net-like patterns. The value of an asbestos deposit depends largely on the extent, width, and closeness of spacing of the veins. The most favorable areas for prospecting for asbestos are the serpentine belts in the western portion of the county. The largest serpentine bodies are in the Flagstaff Hill, Garden Valley, Georgetown, Latrobe, and Webber Creek areas.

Clay

Minor amounts of clay have been mined in El Dorado County. Although not shown on the geologic map, thin layers of clay are interbedded with gravels in the Tertiary river channel deposits. Channel deposits in the Georgetown, Newtown, and Placerville areas were the sources of the clay mined in the county (Aubury, 1906, p. 361).

Dimension Stone

Dimension stone was quarried in El Dorado County starting soon after the beginning of the gold rush. A number of buildings in Placerville, El Dorado, Diamond Springs and Shingle Springs, Coloma, and Lotus were constructed of rhyolite tuff, granite, and greenstone during the 1850's. Also there are many early-day stone walls and fences in the western portion of the county. Much of the stone used in these structures was quarried locally.

Rhyolite tuff of Miocene age was the most widely used stone for these early structures. Some was imported from the Volcano area of Amador County. Greenstone of the Calaveras and Amador groups, granite, and smaller amounts of serpentine, limestone, and talc schist also were used. Large quantities of boulders of andesite of Mio-Pliocene age were used to construct fences, walls, and miners' dams. Many of these were built by Chinese laborers.

In later years the demand for dimension stone for building purposes decreased. However, since 1947, rhyolite tuff has been quarried and processed in a plant in the Newtown area and marketed under the trade name of Sierra Placerite as ornamental stone for use in patios and fireplaces. Also small amounts of rough flagstone composed of rhyolite tuff have been produced intermittently in the Newtown area for the past several years.

Sierra Placerite. Location: sec. 29, T. 10 N., R. 12 E., M. D., 1 mile south of Newtown just northwest of the junction of the Newtown and

Pleasant Valley roads. Ownership: Sierra Placerite, Route 2, Box 252, Placerville, A. E. Nicolazzi, president and Warren Wilson, manager.

Ornamental building stone that is marketed under the trade name of Sierra Placerite is produced. The finished stone is used in fireplaces, patios, outdoor barbecue pits, stone facing, and garden walls. Rhyolite tuff is obtained from a nearby quarry and sawed and split into slabs and blocks. Some of it is fired in kilns. The operation was started in 1947 by R. C. Young and purchased by the present operator in 1954 (Warren Wilson, personal communication, 1955).

Extensive beds of vitric crystal rhyolite tuff of Miocene age occur in the region. In some places in this area the beds are several hundred feet thick. The tuff is fine-grained, light buff to white in color, and contains small plates of black biotite. There are numerous limonite-stained layers in the tuff, commonly in circular or concentric patterns. The quarry, which is quarter of a mile northeast of the plant, is 100 feet long, 50 feet wide, and 15 to 20 feet deep. An auger drill and power loader are used in quarrying. Large blocks of stone are trucked to the plant, while small fragments are sold directly from the quarry as rough stone. An old quarry just north of the plant was worked until 1954.

At the plant the pieces are sawed into slabs of desired thickness with circular stone saws that have carborundum or tungsten carbide teeth. The most common thicknesses are 2, 3, or 5½ inches. The slabs are broken into desired widths, usually about 4 inches, with a hydraulic breaker or splitter. They then are trimmed to any desired length with hand axes. About two thirds of the shaped stone is marketed with natural colors. The remaining third is heated in a brick oven to drive off all contained moisture. The dried stone is then fired in an oil- and gas-fired continuous kiln. The small amount of iron present is oxidized so that the stone is colored to pleasing shades of orange, red, and pink. The lighter colors are obtained by firing at about 1600° F.; a brick-red color is obtained by firing at 2000° F. There is also a small electric kiln on the property for firing special hand-finished pieces. A ceramic glaze is put on novelty items such as desk sets and lamp bases.

Most of the finished product of the past few years has been used in fireplaces and building fronts in the numerous housing developments in the San Francisco Bay Area. The rate of production is as high as 100 tons of finished stone per month (Warren Wilson, personal communication, 1955). Seven men work at the quarry and plant.

Dolomite

A vein of dolomite occurs at the Larkin gold mine, which is 1 mile west of Diamond Springs. This vein, which is as much as 42 feet in width at the surface, is part of the Mother Lode system (Logan, 1947, p. 233). The dolomite has a rusty color because of the presence of iron oxide. Talc, quartz, and pyrite are also present.

Gems and Ornamental Minerals

About 30 small diamonds have been recovered from Tertiary channel deposits in the Smith's Flat area of El Dorado County. The largest of these weighed 1.88 carats (Murdoch and Webb, 1948, p. 130). Diamonds are believed to have originated in ultrabasic igneous rocks.

Crystallized gold in white quartz, which has been used in jewelry, has been found along the Mother Lode belt, particularly in the seam deposits between Placerville and Georgetown. It also has been found in pocket deposits in both the East and West gold belts.

Azurite and malachite occur at some of the copper mines of the foothill copper belt. Quartz crystals have been recovered from veins along the Mother Lode gold belt. Californite and idocrase have been found at the Cosumnes and Pioneer-Lilyama copper mines. Crystals of epidote and garnet have been found at these mines and at the Williams and Grizzly Flat tungsten prospects. Opal with various pleasing shades of brown has been found in the hydraulic mine at Slug Gulch 2 miles east of Fairplay. Occasionally fragments of opalized wood are found in the Tertiary channel deposits.

Limestone

For many years the production of limestone and lime has been a major industry in El Dorado County. At present lime and limestone are the chief mineral products of the county. The Cool-Cave Valley limestone deposit, the largest in the county, was a major source of limestone for a cement plant in the San Francisco area for nearly 30 years (Clark, 1954, p. 440). Four producers supply limestone for use in lime manufacture, sugar beet refining, glass manufacture, steel fluxes, roofing granules, poultry grits, mineral filler, aggregate material, and soil conditioners. Lime-manufacturing plants are active at two of the properties. Much of the finished material is marketed in the San Francisco and Sacramento-Stockton areas.

Some of the largest accessible limestone deposits of the Sierra Nevada are in the county. Many have been worked at one time or another. All of the deposits are composed of fine- to coarse-grained crystalline limestone that ranges from white to bluish-gray in color. On the basis of limited fossil evidence, the limestone is considered to be of Carboniferous age and part of the Calaveras group. All of the deposits are lens shaped, and most have a northerly trend. They are interbedded with metasedimentary or metavolcanic rocks.

Most of the deposits utilized at present are high in calcium and low in magnesium, although one deposit is worked intermittently for magnesian limestone. Many are cut by dikes of fine- to medium-grained diorite, quartz diorite, and their schist equivalents. Also, some of the limestone deposits contain veins of chert. Jointing is prominent in much of the limestone.

The limestone deposits in the county are mined by open-pit and underground methods. In underground mining, shrinkage stopes are employed. At one time glory holes were employed by one producer. At various times one operator produces an entire year's supply with one blast. One producer delivers stone from the quarry to the lime plant via a 3-mile aerial tramway. Finished material from the plants is shipped by both truck and railroad.

Cool-Cave Valley (Coswell-Cave Valley) Deposit. Location: secs. 6, 7, and 18, T. 12 N., R. 9 E., M. D., 4 miles east of Auburn on the south side of the Middle Fork of the American River. Ownership: South $\frac{2}{3}$, Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco; north $\frac{1}{3}$, Ideal Cement Company, 310 Sansome Street, San Francisco.

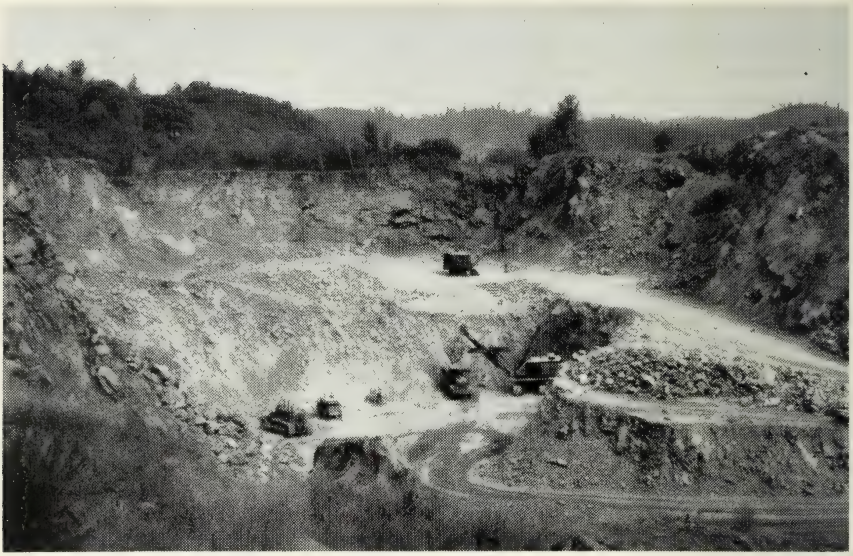


FIGURE 23. Limestone quarry of California Rock and Gravel Company. Camera facing north.

The largest limestone deposit in the county, the Cool-Cave Valley deposit has been a major source of limestone for the cement, lime, and beet-sugar industries for many years. It consists of two north-trending lenses. During the 1880's and 1890's, limestone was quarried from the south lens and burned in stone lime kilns (Clark, 1954, p. 441). Ruins of these old kilns are near State Highway 49. From 1910 to 1940, the Pacific Portland Cement Company operated an extensive quarry at the north end of the north lens by the Middle Fork of the American River. This deep quarry was known as Mountain Quarries. Limestone was sent through a crushing and sizing plant and shipped over a company-owned railroad to Auburn and then to the Pacific Portland Cement plant in Solano County or to beet sugar refineries. In 1942, the quarry was abandoned and the railroad dismantled.

In 1946, the south portion of the north lens, south of Mountain Quarries, was leased by the California Rock and Gravel Company. This concern produces limestone for use in beet-sugar refining and lime manufacturing. A detailed study recently was made of this deposit, the results of which were published in the California Journal of Mines and Geology, vol. 50, July-October 1954, pp. 439-465.

The deposit consists of high-calcium bluish-gray crystalline limestone. The north lens, which is cut by the Middle Fork of the American River near the north end, is about 5500 feet long and has an average width of 400 feet. It was worked to a depth of nearly 800 feet in Mountain Quarries. The south lens, which is crossed by State Highway 49, is 2,000 feet long and nearly 600 feet wide in the middle. A number of samples taken from both lenses averaged more than 97 percent $CaCO_3$ and less than 1 percent $MgCO_3$ (Clark, 1954, p. 454). Country rock is green schist and massive greenstone. Both lenses are cut by dikes of medium-grained diorite and quartz diorite. The limestone is well jointed.

At the California Rock and Gravel Company quarry in the south-central portion of the north lens, limestone is mined by several methods. In 1946 and 1947, it was quarried by benching with 30-foot wagon drill holes. From 1948 to 1952, it was mined with "coyote" holes where adits were driven perpendicular to the quarry face and branches driven perpendicular to the adits. These were loaded with dynamite and an entire year's supply of limestone was dislodged in one blast (Clark, 1954, p. 458). At the present time large benches and 100-foot vertical wagon drill holes are used. About six months' supply is dislodged in one blast. Large fragments remaining from the blast are broken with a drop ball. In the fall of 1955, a new quarry north of the plant was being developed.

Broken stone from the quarry is trucked to a nearby crushing and screening plant. Coarse and medium sizes are trucked to Auburn and shipped by rail to beet-sugar refineries in the Sacramento and San Joaquin Valleys. The finer sizes are trucked to the Diamond Springs Lime Company for lime manufacturing. Until 1954, this concern also supplied limestone to the Vertin Lime Company plant at Rattlesnake Bridge. Undersize is stockpiled and sold as road metal. Twenty-seven men work at the quarry and plant.

Another limestone lens is located about one mile to the west on the Middle Fork of the American River. It also is composed of bluish-gray high-calcium limestone (Clark, 1954, p. 460). The lens, which strikes northwest, is 450 feet long and 50 feet wide. It was worked many years ago, and the stone was burned in a stone lime kiln at the north end.

Diamond Springs Lime Corporation. Location: the plant is in sec. 24, T. 10 N., R. 10 E., M. D., at Diamond Springs; the quarry is in sec. 28, T. 10 N., R. 11 E., M. D., 3 miles to the east. Ownership: Diamond Springs Lime Corporation, Diamond Springs, H. C. Green, manager.

This company operates a lime plant that was erected in 1927 (Logan, 1938, p. 274). Various grades of lime and quicklime are produced for use in steel mills, the building industry, and agriculture. Aggregate material, road metal, and asphalt mix are by-products.

Most of the limestone used in the plant is imported from El Dorado Limestone Company at Shingle Springs and the California Rock and Gravel Company at Cool. Limestone from these two concerns is shipped in by truck or rail and dumped into an underground bunker. From here, it is delivered by clamshell bucket to a storage shed, then screened. As the size required for the kilns averages ¾ of an inch to 1½ inches, oversize stone is sent by belt conveyor to a jaw crusher. Undersize is stockpiled and sold as aggregate or is sent to a hot plant on the property for use in the manufacture of asphalt mix.

From the storage shed, the limestone is belt-conveyed to bins which supply the kilns. From the bins, the limestone goes by belt feeders to two oil-fired 8- by 125-foot inclined rotary kilns. As the limestone from the two suppliers have different physical characteristics, only one type is burned at a time (H. C. Green, personal communication, 1955). A precipitator at the head of the conveyor belt collects much of the dust.

Lime from the kilns goes through two 4- by 48-foot coolers under the kilns and then by pan conveyor and bucket elevator to two bins. From these bins it is sent by a screw conveyor and more bucket ele-

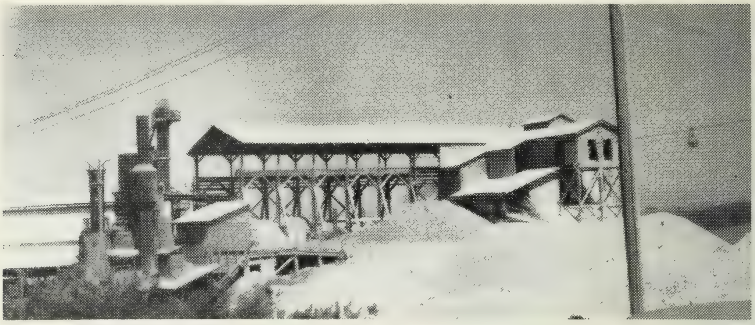


FIGURE 24. Diamond Springs Lime company plant.

vators either to a hydrator or to a rolling mill for fine grinding. Some of the lime is sent to a recently installed unit consisting of a slaker, drier, and tube mill for the production of ''Marvel,'' a trade name for a high-calcium lime of minus 100-mesh size. In the summer, when the company-owned quarry is in operation, 7 percent magnesian lime is produced.

The various finished products are sent to storage bins. Material from the storage bins is bagged or bulk-loaded into railroad cars and trucks for shipment. About half of the finished product is sold to steel plants in the San Francisco Bay area as fluxing material (H. C. Green, personal communication, 1955). Another major consumer is the building industry, in which lime is used for manufacturing plaster, stucco, and mortar. Smaller amounts are used in agriculture and the chemical industry.

The limestone deposit, 3 miles east of the plant, is mined during the summer. A limestone lens, which is about 2,500 feet long and as much as 500 feet wide, occurs in metasedimentary rocks of the Calaveras group. It strikes north and has a vertical dip. Jointing is common. The limestone is fine-grained and ranges from white to bluish-gray in color.

The stone is quarried in 30-foot benches with wagon drills and jackhammers. The broken stone is loaded by power shovel into dump trucks and delivered to a primary jaw crusher. From the jaw crusher, it goes by conveyor belt to storage bins that serve the aerial tramway. This tramway, 3 miles long, uses 149 buckets of 800 pounds capacity each and can deliver as much as 30 tons an hour to the plant.

El Dorado Limestone Company. Location: sec. 15 and 22, T. 9 N., R. 9 E., M. D., 3 miles southwest of Shingle Springs. Ownership: El Dorado Limestone Company, Shingle Springs, California, J. H. Bell, president; C. R. Nichols, general manager; and F. G. DeBerry, mine superintendent.

The El Dorado Limestone Company produces high-calcium limestone for various uses. Finished material is used in the manufacture of lime, by steel mills, glass manufacturers, in beet-sugar refining, and in construction materials.

The present concern, which was formed in 1931, is a successor to El Dorado Lime and Minerals Company, which began mining the deposit in 1918 (Logan, 1947, p. 230). Prior to that date, limestone was

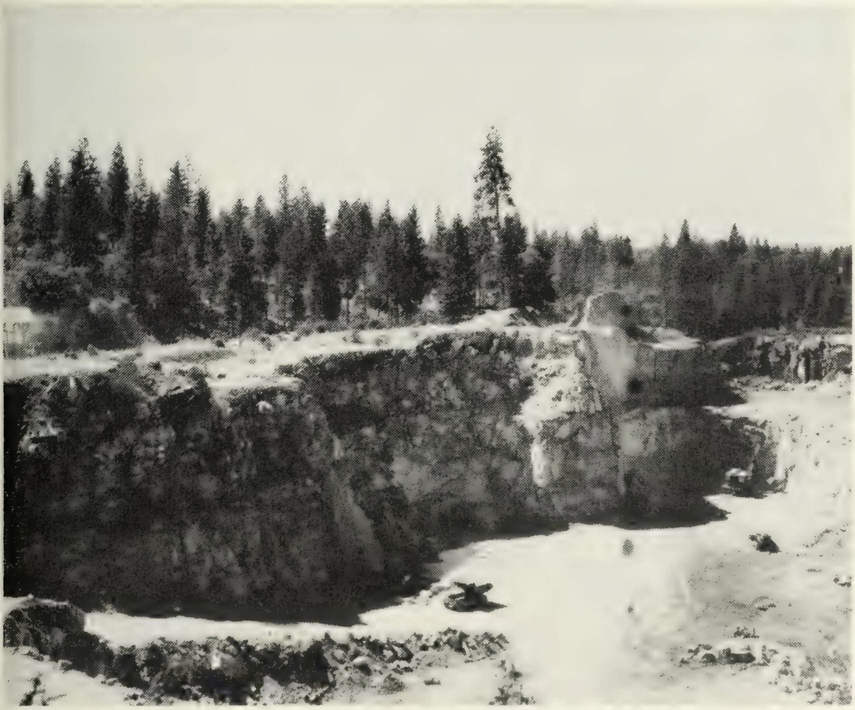


FIGURE 25. Limestone quarry of the Diamond Springs Lime company. Camera facing west.

quarried just north of the mine. This was burned in nearby stone lime kilns and the lime used for building purposes. Ruins of these old lime kilns may still be seen.

This deposit consists of two parallel northwest-trending lenses of crystalline limestone which are part of a belt of metasedimentary rocks of the Calaveras group. Dip is vertical or nearly so. The two lenses are from a few to more than 50 feet apart. Country rock is slate and schist. The east limestone lens has an average width of 60 feet; the west lens has an average width of 40 feet. Several dikes of fine- to medium-grained granodiorite cut both limestone lenses. Because of the thick soil overburden, outcrop, of the deposit are poor. It is shown on the U. S. Geological Survey Placerville folio as being extremely limited in size (Lindgren and Turner, 1894).

The limestone has an even, medium- to coarse-grained texture. It is mostly grayish-white in color, although some gray limestone is present. Jointing is prominent, the principal joint planes dipping both north and south. All of the limestone is high in calcium and low in silica and magnesium. Sixty-seven carloads shipped to one user averaged 97.65 percent $CaCO_3$ and 0.24 percent SiO_2 (Logan, 1947, p. 231).

The main working entry is a 1,000-foot three-compartment vertical shaft sunk near the east wall of the east lens. The deepest workings are on the 800-foot level. Crosscuts extend from the shaft stations to the west lens. No timbering is required. Good ventilation is facilitated by a raise connecting the 150-foot level with the surface south of the shaft,

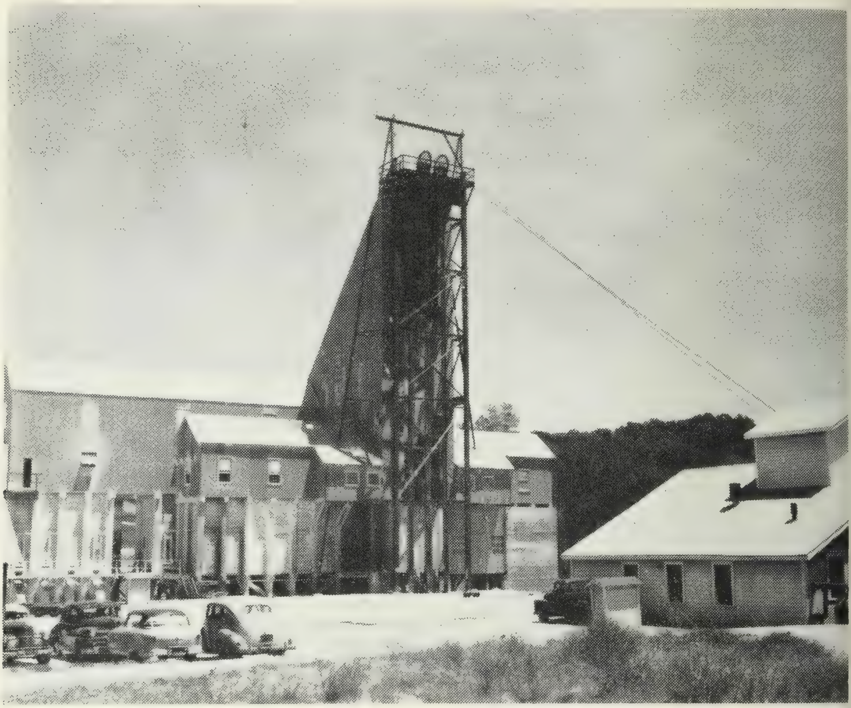


FIGURE 26. El Dorado Limestone Company—headframe with hoist house to right, crushing and sizing plant to left. Camera facing east.

a raise from this level to the old quarry north of the shaft, and numerous raises that connect the lower levels.

For many years shrinkage stopes have been employed in the mine. The main haulageways are drifts about 20 feet wide and 8 feet high that have been driven north and south from the shaft stations in both the east and west lenses. In developing a stope, short crosscuts are driven perpendicularly from the main haulageways; the ends of these are used as drawpoints and are connected by ore chutes to the bottoms of the stopes at the sides. The bottoms of the stopes have an inverted V-shape so the loose rock flows down ore chutes to the drawpoints. The lowest parts of the stopes are about 12 feet above the level of the roofs of the drifts.

Gardner Denver drifters and liners and 30 percent ammonia dynamite are used for drilling and blasting. The rock is drilled and blasted in 5-foot slices in the stopes. Broken rock is drawn from the ore chutes and is allowed to pile up at the end of the crosscuts. Track-mounted Eimco mucking machines in the short crosscuts load the broken rock into a 3½-ton ore car in the haulageway. Occasionally large chunks are blasted in the haulageways. The rock is delivered to the loading pockets at the shaft station where the larger pieces are broken on the grizzlies with sledge hammers.

Limestone is mined in stopes in both lenses on the 650-foot level. North and south drifts are being driven on the 800-foot level, preparatory to the development of new stopes between that level and the 650-foot level. When the stopes have been mined up to the level above,

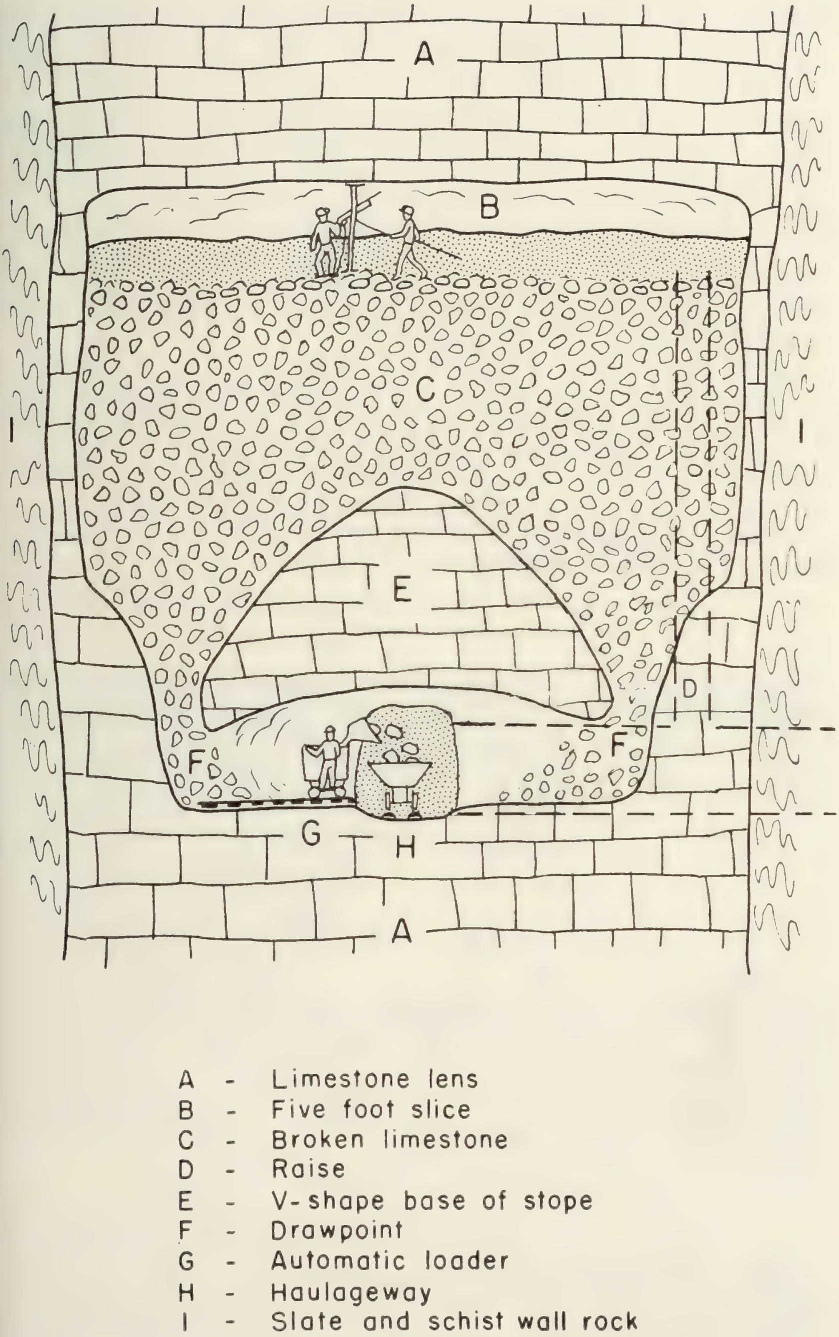

A
B
C
E
D
F
F
G
H
A
I
I
A - Limestone lens
B - Five foot slice
C - Broken limestone
D - Raise
E - V-shape base of stope
F - Drawpoint
G - Automatic loader
H - Haulageway
I - Slate and schist wall rock

FIGURE 27. Cross-section of shrinkage stope at El Dorado Limestone Company limestone mine.

the remaining pillars on that level also are mined out. Completed stopes reach maximum dimensions of 300 feet in height, 600 feet in length, and 70 feet in width. The limestone is mined to within a few feet of the wall rock.

Limestone is hoisted in 2-ton skips and deposited in a 200-ton silo-type bin mounted on the 100-foot steel headframe. From the bin, the rock passes by gravity through a Kue-Ken crusher, vibrating screens, and trommels. During this process, the material is hand picked on conveyor belts to remove fragments containing schist or dike rock. Sized material is delivered to separate bins from which it can be loaded into railroad cars or trucks. Some of the coarser material is stacked in yard stockpiles. The company has 1.9 miles of spur track which connects with the Southern Pacific Railroad.

The most important of the finished products are stone used in the manufacture of lime, roofing gravel, material used in glass-making plants, and sugar rock. The stone used in lime manufacturing is shipped to the Diamond Springs Lime Company, Diamond Springs. Sugar rock is sent to beet-sugar refineries in the Sacramento-Stockton area. Other products are fluxing material for open-hearth steel furnaces and filler material used in the manufacture of paints and linoleum. Agricultural limestone also is produced.

Marble Valley (Schwalin) Deposit. Location: secs. 8 and 17, T. 9 N., R. 9 E., M. D., 2 miles southeast of Clarksville in Marble Valley. Own-

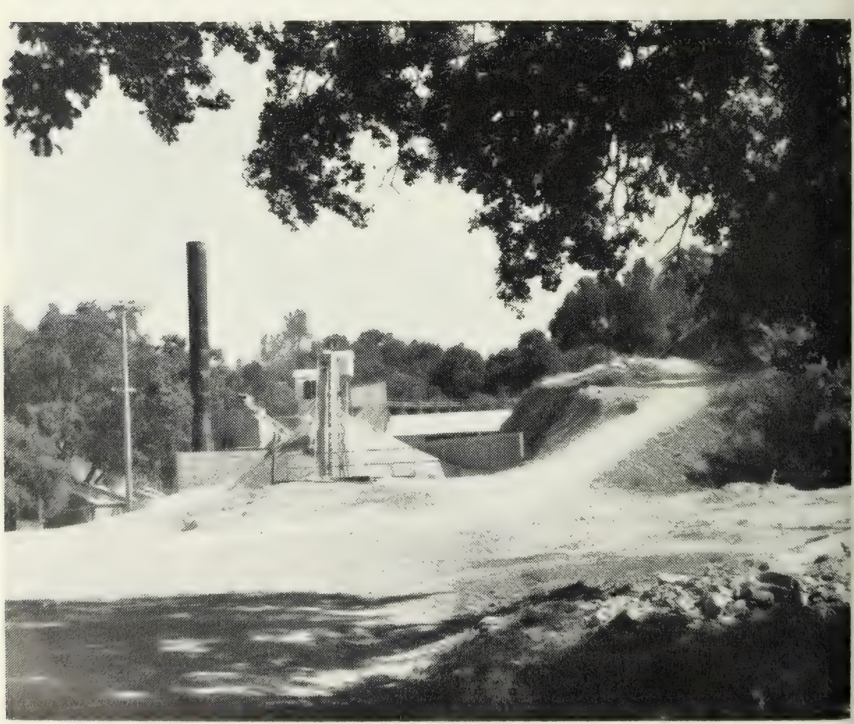


FIGURE 28. Semon Lime Company plant near Rattlesnake Bridge. Camera facing south.

ership: Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco, California.

Years ago, limestone was quarried at this deposit and burned in a vertical kiln a quarter of a mile to the west. The last period of operation was about 1918 (Henry Cowell Lime and Cement Company, personal communication, 1955).

Limestone crops out at intervals for a distance of nearly 4,000 feet, but the total extent of the deposit is unknown. The deposit ranges from less than 100 to 200 feet in width. It apparently is lensoid and has a north-northwest strike. The limestone is medium grained and ranges from white to light bluish-gray in color. An analysis of a composite sample taken by C. A. Logan is as follows (Logan, 1947, p. 232):

	Percent
Insoluble	0.43
Ferric and aluminum oxide	0.42
Calcium carbonate	98.80
Magnesium carbonate	0.30
	99.95

The deposit is developed by two open quarries. The north quarry is about 150 feet wide and several hundred feet long with quarry faces up to 40 feet high. The south quarry is 180 feet wide, 300 feet long, and 20 to 25 feet deep.

Rattlesnake Bridge (Alabaster Cave, Rattlesnake Bar) Deposit. Location: sec. 15, T. 11 N., R. 8 E., M. D., 1 mile east of Rattlesnake Bridge and 5 miles south of Auburn. Ownership: Semon Lime Company, Auburn, H. S. Dahlman, manager.

This limestone deposit, which also has been known as the Alabaster Cave deposit, has been worked intermittently since the 1860's by a number of concerns. There is an old stone lime kiln near the Rattlesnake Bridge road, which crosses the northern portion of the deposit. From 1930 to 1942, the Auburn Chemical Lime Company worked the deposit. Limestone from the south end of the deposit was treated at a crushing and sizing plant and sent through a lime plant. Much of the lime manufactured during the 1930's was sold to gold mines for use in cyanidation (Logan, 1947, p. 223).

From 1942 to 1954 there was little output from the quarries, as most of the limestone used at the plant was purchased from the California Rock and Gravel Company at Cool. From 1946 to 1948, the plant was operated by the Auburn Lime Products Company; from 1949 to 1954 by the Hughes-Vertin Lime Company; and from 1954 to 1955 by the Vertin Lime Company. In July 1955, the Semon Lime Company purchased the holdings and has operated the property since (H. S. Dahlman, personal communication, 1955). A new 7- x 110-foot rotary kiln and increased storage facilities were installed in 1953. In 1954, a new quarry was opened in the north end of the deposit. At present several grades of lime, quicklime, and hydrated lime are manufactured and marketed under the trade name "Versatile." Sized limestone also is sold.

The deposit is a lens of coarse-grained crystalline limestone ranging from white to bluish-gray in color. It strikes north and dips steeply east. It is about 4,000 feet long and 80 to 100 feet wide. Parallel joints are prominent; the principal joint planes strike west and dip steeply south. Most of the limestone is high in calcium carbonate (97 to 99 per cent) (H. S. Dahlman, personal communication, 1955). At one time there were a number of natural caves, which since have been quarried out. Country rock is amphibolite with small amounts of serpentine. There are several bands of amphibolite and chlorite schist up to several feet thick in the limestone, and these are troublesome in quarrying operations.

The deposit is developed by four quarries. Two are located south of the plant: one, 300 feet long, extends north from the south end of the deposit and the other 475 feet long extends south from the plant. They are up to 75 feet deep and 25 to 50 feet wide. These were the main source of limestone prior to World War II. An old quarry immediately north of the road was the source of rock from the old stone lime kiln.

Limestone is mined from 20-foot benches in a quarry about 300 feet long and 25 to 50 feet wide in the north end of the deposit. Wagon drills with 40 percent gelatin dynamite are used; large boulders are broken with jackhammers. Primary crushing is done in the quarry and secondary crushing and screening at the plant. The plus $\frac{1}{4}$-inch stone is sent either to the new 7- by 110-foot oil-fired inclined rotary kiln or two older 4- by 60-foot kilns. Lime passes through a rotary cooler and into a storage bin for sacking, bulk loading, or hydration. Most of the lime produced is shipped to steel plants in the San Francisco Bay area or to the building-trades industry in the Stockton-Sacramento area. Minus $\frac{1}{4}$-inch rock is screened into several sizes and sold as roofing granules, chicken grits, limestone flour, and road metal. Fifteen men work at the plant and quarry.

Slug Gulch (Cosumnes) Deposit. Location: secs. 24, 25, and 26, T. 9 N., R. 12 E., M. D., by the Middle Fork of the Cosumnes River, 3 miles northeast of Fairplay. Ownership: Clifford Smith, Somerset.

This limestone deposit crops out for a distance of $1\frac{1}{2}$ miles in a northeast direction from Slug Gulch to north of Rocky Bar on the Cosumnes River. It is lensoid and has an average width of several hundred feet. The limestone is medium- to coarse-grained in texture and ranges from white to bluish-gray in color. Other than the quarrying of a small amount of limestone at the north end for use as road metal, there has been no work on the deposit (Lee Miller, personal communication, 1955). The deposit is accessible by several dirt roads, one of which extends east from Fairplay to the Cosumnes copper mine, which is just west of the deposit.

Mineral Paint

Although the production of mineral paint has never been recorded from El Dorado County, samples of both red and yellow ochre were submitted to the Division of Mines Laboratory many years ago (Logan, 1927, p. 444).

Silica

Large quantities of quartz occur in El Dorado County. There are not only numerous massive quartz veins in the county, but quartz is a major constituent of many of the other rocks, particularly quartzite and granitic rocks. Also, quartz pebbles and cobbles are common in Tertiary and Recent stream gravels. Quartz has been mined from three properties in the county (see tabulated list under Silica).

Pure silica is used in glass-making, in glazes for porcelain and pottery, as fluxing material in foundries and smelting, in the manufacture of ferro-silicon for the steel industry, and in abrasives. Much of the raw material for these industries must be beneficiated. Although the majority of silica for these uses is obtained from other sources, the massive quartz veins, quartzite bodies, and quartzitic gravels of the Sierra Nevada exist as potential sources of silica.

Slate

Slate has been mined in El Dorado County since about 1887. The Placerville area has been the largest and most consistent source of slate in California. At present most of the slate mined in California is from El Dorado County.

Nearly all of the slate mines in the county are between Placerville and Kelsey, where the Mariposa slate makes up a northwest-trending belt that averages 2 miles in width. Dip is vertical or steeply to the northeast. The slate is bluish-black in color when fresh and weathers to a brown or greenish-gray. Much of it is in uniform beds, with only a few small quartz veinlets or minor amounts of pyrite as impurities.

For many years, most of the slate mined in the county was dimension slate or squares, a unit equivalent of 100 square feet. The peak in slate production was reached in 1906 when 10,000 squares valued at $100,000 were produced. Dimension slate was used principally in shingles. Smaller amounts were used for blackboards, school slates, sinks, and as finished stone in homes. Major sources of dimension slate were the El Dorado Slate Products Company, which operated a quarry on the south side of Big Canyon 1½ miles north of Placerville, and the Eureka Slate Company, which owned a quarry 1 mile south of Kelsey. Slate from the Eureka quarry was delivered to Placerville via a 13,000-foot aerial cableway, which crossed the American River at an elevation of 600 feet above the bed of the river.

Because of the great amount of hand labor required and the resulting high costs, the production of dimension slate in El Dorado County gradually declined during the 1920's and finally ceased altogether. However, about this time the demand for crushed and ground slate for use as roofing granules and as filler material increased. In 1928, the old Chili Bar quarry was reopened by the Pacific Minerals Company. At present, this is the only active slate property in the county.

Chili Bar Mine. Location: sec. 36, T. 11 N., R. 10 E., M. D., on the south side of the South Fork of the American River just east of the Chili Bar bridge, 3½ miles north of Placerville. Ownership: Pacific Minerals Company, Ltd., 339 10th Street, Richmond, California; G. H. Bishop, manager; Edward Bishop, foreman.

Originally an open-pit operation, the Chili Bar slate mine first was worked from 1887 to 1897 (Logan, 1926, p. 448). In these early operations, roofing shingles and other forms of dimension slate were produced. The property was idle until 1928, when it was reopened by the present operator. An underground mine was developed and a

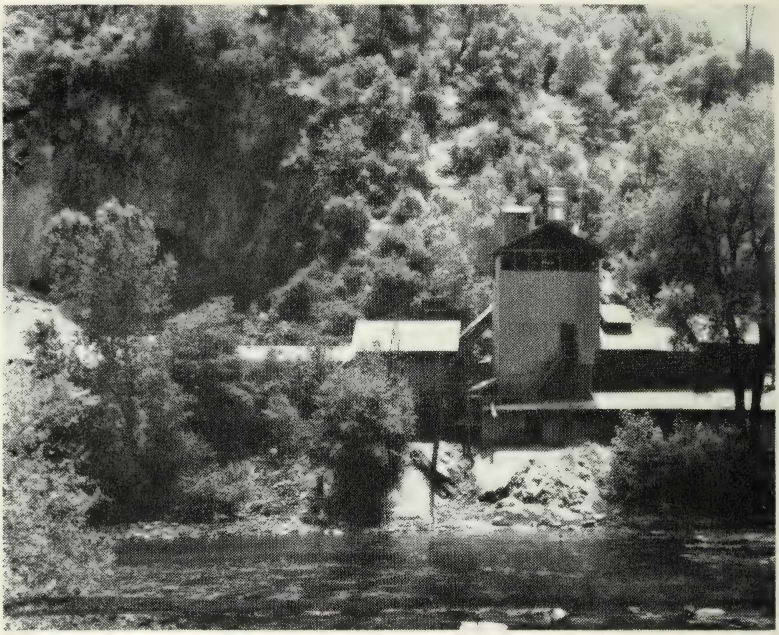


FIGURE 29. Pacific Minerals Company slate mine and crushing plant at Chili Bar, by South Fork American River. Camera facing south.

grinding and sizing plant installed (G. H. Bishop, personal communication, 1954). Since that date, roofing granules and slate-dust filler have been the principal products with the exception of minor amounts of dimension slate.

Dark fissile slate of the Mariposa formation occurs in a northwest-trending belt about 2 miles wide. The slaty cleavage strikes N. 10° W. and dips 85° NE. Metasedimentary rocks of the Calaveras group lie east of this belt and fine-grained metadiabase is exposed to the west. The mine is about a quarter of a mile east of the west boundary of the slate. Small quartz stringers mostly less than an inch wide are present here and there in the slate. Several hundred yards east of the mine are several quartz stringers that contain pyrite and some gold.

The mine is worked through a southeast-trending drift adit which is the main haulageway. Until 1953, the slate was mined in shrinkage stopes. These were abandoned, and at present the slate is mined by overhand stoping in pillar and chamber workings. A stope is developed by driving a drift for about 150 feet; this is then widened to 40 to 50 feet and heightened to about 18 feet. Broken slate is removed for convenient access, and full-width overhand slices, each about 18 feet high, are removed from the back of the long stope, the miners always standing on the broken slate. The stopes are finally completed leaving large open chambers with pillars between. The slate has been mined for distances of 500 feet east and west of the main haulageway, about 800 feet southeast of the portal. Little or no timber is used in the underground workings. Ingersoll-Rand and Chicago pneumatic long-shell drifters with 4-foot changes in steel and ''carset'' bits are used.

A round usually consists of about 200 60-foot holes in an 18- by 40-foot face. ''Geladine'' ready-split stick powder with a millisecond delay firing system is used in blasting.

Broken slate is loaded into ore cars by pneumatic mucking machines and hand-trammed to the raw-feed hopper 100 feet in from the adit portal. The slate is sent through a 2-inch grizzly. At the plant, which is just west of the adit portal, the minus 2-inch material falls into a rotary drier, while plus 2-inch slate goes to two Williams Jumbo Junior hammer mills. The crushed slate is sent through four Tyler Hum-mer double-deck vibrating screens. Plus 10-mesh material is returned to the circuit for re-crushing. Minus 10- plus 35-mesh material is treated with a special saturating oil and bagged for shipment as roofing granules. Minus 35-mesh material is further ground in a Joshua Hendy ball mill, elevated, and air classified in a Sturdevant air classifier. Two nominal sizes (200-mesh and 325-mesh) are prepared, bagged in paper sacks, and shipped to the market as slate-dust filler. Plant output is about 40 percent granules and 60 percent filler dust (Edward Bishop, personal communication, 1955).

Ten are employed at the mine and mill. The mine operates on one shift and the mill on two shifts per day. Bagged material is trucked to Placerville for rail shipment. Much of the finished product is shipped to the San Francisco and Los Angeles areas, and some is shipped to Oregon.

Soapstone

For many years varying amounts of soapstone have been mined in El Dorado County. Soapstone is mined at the Swift property by the Pacific Minerals Company and intermittently at the Bernett and Hayden properties. It is marketed in the San Francisco Bay area for use as a carrier in insecticide dust.

Sawed slabs and blocks of soapstone were produced as early as the 1880's in El Dorado County (Logan, 1926, p. 450). These were used as building materials and for tubs, sinks, and stoves. Later substantial quantities of soapstone were mined for use as filler material for rubber, cloth, paint, paper, roofing and as a lubricant and in electrical insulation. Sources of soapstone during these times were the Swift mine near Latrobe, which operated from 1916-24, and the Rossi or Shingle Springs mine south of Shingle Springs, which was active from 1919-28. The Swift mine was reopened in 1928 by the Pacific Minerals Company and has been continuously active since.

Soapstone deposits in the Sierra Nevada are in or near talc-rich amphibolite schist or serpentine bodies in the western foothills. Most of the soapstone that has been mined in El Dorado County has been from the Latrobe-Shingle Springs area where there are extensive bodies of serpentine. The deposits range from small lenses a few inches thick to those hundreds of feet in extent. The soapstone is most commonly greenish-gray in color. Because of the iron oxide present in most Sierran soapstone, it has not been used in ceramics.

Bernett Property. Location: sec. 23, T. 9 N., R. 9 E., M. D., 4 miles southwest of Shingle Springs adjacent to the Southern Pacific Railroad. Ownership: D. P. Bernett, Shingle Springs, California; leased by Frank Harris, 580 North L Street, Livermore, California.

Soapstone has been mined intermittently at this property by Mr. Harris since 1953. It is mined by stripping with a bulldozer. The soapstone is trucked in crude form to the Industrial Minerals and Chemical Company in Berkeley, where it is ground for use as an insecticide carrier.

The deposit is a north-trending body of talc schist at least 500 feet in length. Width of the body ranges from 40 to 60 feet, and it has been bulldozed to a depth of 10 feet. The schist is fine grained, and its color ranges from light gray to reddish brown, the latter caused by iron oxide staining. The presence of iron oxide does not lower its value as an insecticide carrier (Frank Harris, personal communication, 1954). The pit is approximately 100 feet long and ranges from 40 to 60 feet in width.

Hayden Property. Location: sec. 7, T. 9 N., R. 10 E., M. D., 1¾ miles southwest of Shingle Springs. Ownership: Mark Hayden, Shingle Springs; leased to Industrial Minerals and Chemicals Company of Berkeley.

Since early 1955 the Industrial Minerals and Chemical Company has mined soapstone intermittently from this property. It is trucked to the company's grinding plant at Florin, Sacramento County, and prepared for use in insecticides.

The deposit is a lensoid body of iron oxide-stained greenish soapstone which is on the west side of a small body of metasedimentary rock enclosed in greenstone. The soapstone is quarried from an open cut which is about 100 feet long, 40 feet wide, with a 20-foot face at the north end. A jackhammer is used in drilling. The excavated material is loaded into trucks with a Caterpillar loader. Frank Harris of Livermore has the contract to mine and haul the ore to plant.

Pacific Minerals (Swift) Mine. Location: sec. 35, T. 9 N., R. 9 E., M. D., 3 miles northeast of Latrobe. Ownership: Rufus Swift, Shingle Springs; leased by Pacific Minerals Company, Ltd., 337 10th Street, Richmond, California; George McKenzie, mine foreman.

This property was worked originally prior to 1920 (Logan, 1920, p. 433). It was active again during the early 1920's. In these early operations, soapstone was mined in underground workings by hand labor, using augers and drills. The soapstone was shipped to San Francisco where it was used for coating in prepared roofing. The workings caved around 1924, and the mine was shut down (Logan, 1926, p. 451). In 1928, the property was reopened by the present operator and has been worked continuously since that date (George McKenzie, personal communication, 1955).

Until recently, the operation was seasonal, generally running from March through September, but now it is a year-around operation. The crude soapstone is shipped by rail to grinding mills in the San Francisco Bay area where it is prepared for use in insecticides.

The soapstone forms in a lensoid body that is as much as 100 feet wide. It strikes north-northwest and dips moderately to steeply northeast. The soapstone is greenish-blue in color, although much is stained with iron oxide. Country rock is slaty greenstone and metasedimentary rocks.

From 1928 to the late 1930's the mine was worked by underground methods. During that time the main entry was a 220-foot west-trending crosscut adit. About 60 feet in from the portal the main drifts were driven 120 feet north and 200 feet south. Two other drifts, one east and the other west of the main drifts and each 200 feet long, were driven from the main drifts.

In the latter 1930's, the central portion of the mine caved (George McKenzie, personal communication, 1955). Since then soapstone has been mined from an open pit. The main pit is 175 feet long, 35 to 70 feet wide, and has a 75-foot face at the north end. There are two smaller pits at the north end of the deposit.

A jackhammer powered by a 210-cubic-foot compressor is used for drilling. The ore is blasted and loaded into a 5-ton dump truck by a D-4 Caterpillar tractor-loader. The soapstone is trucked about 800 feet and deposited into loading bins by the tracks of the Southern Pacific Railroad. A concrete stockpiling ramp, which can accommodate 2000 tons of ore, was completed in 1955. Three men work at the mine.

Stone

Besides dimension stone and slate, which have been described in separate articles, El Dorado County is a source of sand and gravel, crushed rock, riprap, and road metal. Most of the output is used locally.

The Harms Brothers Construction Company of Sacramento produces crushed rock at a plant just south of Placerville which is used as asphalt mix. Sand, gravel, and crushed rock are produced by the Cold Springs Sand and Gravel Company from Webber Creek 4 miles west of Placerville. H. C. Anderson produces sand derived from decomposed granite and gravel from the Upper Truckee River; these are used in a batching plant at Meyers for ready-mix concrete. Sand and gravel also are produced by Archibald Butler of Meyers from the Upper Truckee River.

Sand and gravel deposits largely consist of accumulations of sand, pebbles, cobbles, and boulders that have been deposited by stream action. They are poorly sorted and are elongated in the direction of stream flow. These deposits are derived from the more weather-resistant rocks and are composed of chert, metachert, quartz, quartzite, greenstone, and granitic rocks. Sand and gravel deposits are found in stream channels of both Recent and Tertiary age. Most are deficient in the finer sizes. The most extensive deposits in the county are near Placerville, where large quantities of gravel have accumulated from hydraulic mining, along the South Fork of the American River in the Coloma-Lotus area, and along the Middle Fork of the American River east of Auburn.

Coarse quartzitic sand derived from decomposed granite and granodiorite is recovered by the California Division of Highways from an extensive pit 1 mile northwest of Coloma by State Highway 49. The sand is used both in highway repair work and in asphalt mix. Several other smaller sand pits intermittently operated by the state are on U. S. Highway 50 between Placerville and Echo Summit and just south of Tahoe Valley. The El Dorado County road department mines coarse sand from a number of small open pits in the western portion of the county, particularly in the region northwest of Shingle Springs.

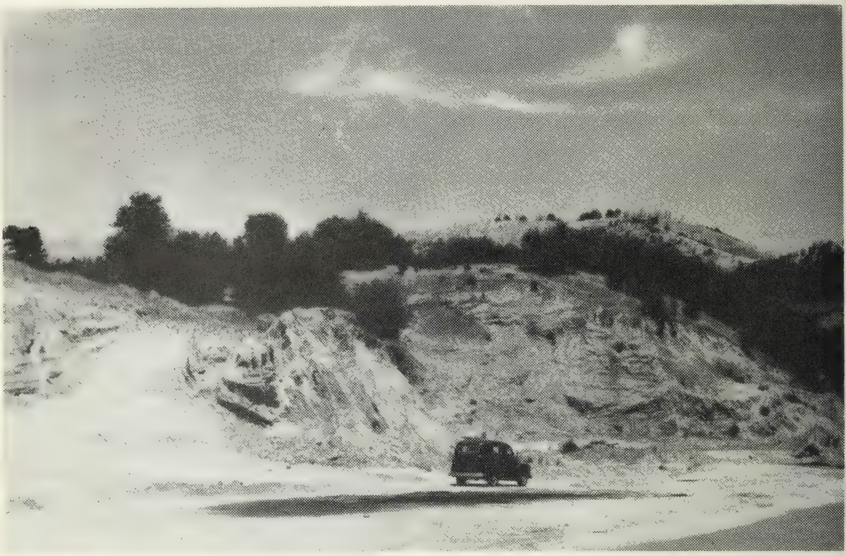


FIGURE 30. State Division of Highways sand pit, in deeply weathered granite in Coloma area. Camera facing east.

Waste limestone from the plants of the California Rock and Gravel Company at Cool and the Diamond Springs Lime Company at Diamond Springs is sold as road metal and fill. Serpentine, which is used by the county road department as road metal, is quarried at the Hummingbird Ranch 1 mile southwest of Garden Valley. Another smaller open pit in serpentine has been worked just north of Four Corners.

Large quantities of broken granodiorite have been used as riprap in the rebuilding and repair of U. S. Highway 50 over Echo Summit, as well as in repair work on State Highways 49, 88, and 89. Considerable quantities of broken metachert and quartzite of the Calaveras group were quarried recently at Hazel Valley for use in the construction of the Sly Park Dam, a combination earth and rock-fill dam.

Cold Springs Sand and Gravel Company. Location: sec. 9, T. 10 N., R. 10 E., M. D., on Webber Creek, 4 miles west of Placerville. Ownership: Jerry Brown, Placerville; leased to L. D. Forni of Placerville.

From 1950 to April 1953, sand, gravel, and crushed rock were produced from this deposit by El Dorado Rock and Sand Company. Since April 1953, the property has been leased by L. D. Forni who now operates it under the name of Cold Springs Sand and Gravel Company (L. D. Forni, personal communication, 1955). A wide variety of aggregate that is marketed in the Placerville area is produced. The output is as much as 300 tons of finished material per day. Since August 1955, waste rock from the Sierra Placerite operation (see Dimension Stone herein) in the Newton area has been prepared for roofing rock.

Sand and gravel are excavated from the banks of Webber Creek by a dragline mounted on a truck. An end-dump truck hauls the excavated material a quarter of a mile to the aggregate plant. At the plant, the material falls through a 9-inch grizzly and belt conveyed to the screening tower. Oversize is sent through a primary jaw crusher and a secondary gyratory crusher and returned to the circuit. A sand drag is used for sand production. Products from the plant fall into two elevated bins from which trucks are loaded. Considerable amounts of aggregate are stockpiled in the yard.

Waste rock from the Sierra Placerite operation consists of buff to red-colored rhyolite tuff. This is crushed to a $\frac{3}{4}$-inch size in the plant and loaded into 80-pound sacks. This material is marketed as roofing rock.

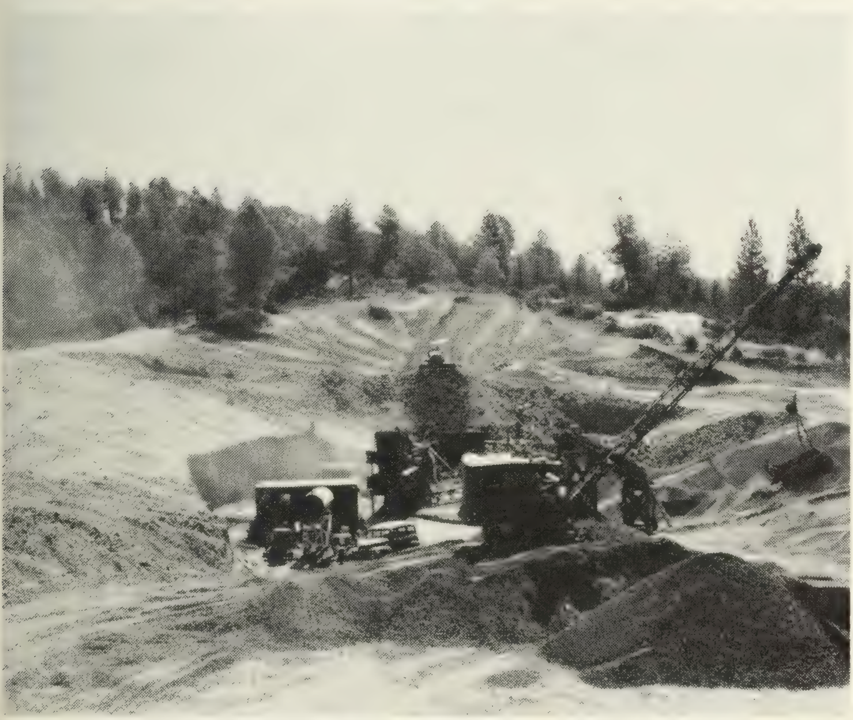


FIGURE 31. Excavating gravel at Harms pit in Coon Hollow. Camera facing south.

Harms Pit. Location: sec. 18, T. 10 N., R. 11 E., M. D., in Coon Hollow, 1 mile south of Placerville. Ownership: Harms Brothers Construction Company, Sacramento, Wally Basanko, foreman.

Since early 1955 the Harms Brothers Construction Company of Sacramento have operated a portable hot-mix plant. The output is used for surfacing the new U. S. Highway 50 bypass in Placerville. Plant capacity is about 100 tons per hour (Wally Basanko, personal communication, 1955).

Andesitic detritus and some hydraulic mine tailings containing quartz, granite, and chert pebbles and cobbles are excavated by a bulldozer. Excavated material is belt-conveyed to an Austin Western portable crushing and sizing plant. Two products are stockpiled by belt conveyors adjacent to the plant, minus $\frac{7}{16}$-inch and plus $\frac{7}{16}$- minus $\frac{3}{4}$-inch material. A Northwest power shovel with a clamshell bucket deposits the graded material in kiln-receiving bins. From here the material is draw-blended on a belt conveyor and dumped into an oil-fired kiln. In the kiln the aggregate is heated to 300° F. A bucket elevator deposits the kiln product into an elevated surge bin. From the surge bin the aggregate is dropped into an elevated pug mill along with pre-heated oil. From the pug mill, the hot mix is loaded directly into end-dump trucks and hauled to the job site.

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TABULATION OF EL DORADO COUNTY MINERAL DEPOSITS

The following list of mineral deposits of El Dorado County is arranged alphabetically by commodity and by name of deposit or mine. Numbers which appear in the left-hand column under the heading *Map No.* refer to the Geologic Maps of El Dorado County Showing Mines and Mineral Deposits, plates 10 and 11. The names and numbers in parenthesis in the last column refer to the accompanying bibliography. The first number after the author's name is the year of publication, and is separated from the page reference by a colon. Other references are separated by semicolons. The term "herein" refers to a description in the text.

CHROMITE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Apex	Not determined	18	13N	11E	MD	One mile southwest of Volcanoville. About 8 tons of ore mined from open pit in 1918. (Cater and others 51:163.)
	Austin		25	13N	10E	MD	See Knoff.
1	Black Oak (Cassiorni)	Not determined	23	12N	10E	MD	Two miles south of Georgetown on ridge west of Traverse Creek. Active 1918 when 36 tons of ore produced and 1942-43 when 107 tons containing 47.5 percent Cr produced. Lenses and pods of coarse chromite in serpentine strike northeast and dip southeast. Developed by open cuts and three 40-ft. shafts. (Bradley and others 18:132; Cater and others 51:161.)
	Bonanza King						Part of Pillikin mine.
2	Bonetti	W. J. Varozza, Shingle Springs	7	8N	10E	MD	Three and one-half miles east of Latrobe and northwest of Big Canyon Creek. Active 1917 and 1942. A 1- to 3-ft. lens of chromite 60 ft. long in dunite strikes N. 28E. and dips 70° SE; estimated to contain 200 tons of ore. (Bradley and others 18:132; Cater and others 51:123.)
	Brandon	Robert D. Domecq et al., Route 1, Box 39, Shingle Springs	12	8N	9E	MD	Three miles east of Latrobe on ridge between Hungry Hollow and Indian Creeks. Active 1918 when four carloads of ore produced. A series of northwest-trending chromite pods in dunite. Developed by open cuts. (Bradley and others 18:132; Cater and others 51:122-123.)

CHROMITE (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Bryant	Stanley S. Bryant, R.F.D. Box 38, Shingle Springs	13	8N	9E	MD	On west bank of Big Canyon Creek $2\frac{1}{2}$ miles south of Brandon Corner. Active 1918. A northeast-trending ore body. (Cater and others 51:122.)
3	Burnett	F. L. Burnett, 469 S. Washington, Placerville	3 34	10N 11N	8E 8E	MD MD	One mile southwest of Salmon Falls on the north side American River. Active in 1918 when 139 tons of ore produced. Layered and disseminated bodies of chromite that strike northwest occur in a zone several hundred feet long. Developed by open cuts and shallow shafts. (Allen 41:138; Cater and others 51:151-152.)
	Buzzard Mill	A. C. Darrington, Repressa					Located on Darrington Ranch. During World War 1, chromite concentrated in 5-stamp mill with Overstrom concentrator. (Bradley and others 18:132.)
	Cassiorni						See Black Oak.
4	Central Pacific Railroad	D. O. Niegel, Cool	23	12N	9E	MD	Two miles southwest of Greenwood. Active 1916-18 when about 250 tons of ore were mined. A northwest-trending lens of 35-41% ore occurs in peridotite. Developed by open cuts. (Cater and others 51:16C.)
	Central Railroad	United States of America (withdrawn for federal reservoir site)	21	11N	8E	MD	One mile northwest of Pillikin mine. A northwest-striking zone of low-grade disseminated ore developed by adits and 200-ft. shaft. (Allen 41,38.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
5	Chaix	Roy Chaix, et al., Box 87, Placerville	14	8N	9E	MD	(Bradley and others 18:132-133; Averill 43:140; Cater and others 51:124; herein.)
	Chrome Divide	Georgetown Lumber Co., Georgetown	25	13N	10E	MD	Three miles northeast of Georgetown. Active 1941-43 when 51 tons of chromite produced Pods and lenses of chromite in serpentine strike northwest. (Cater and others 51:162.)
	Chrome Gulch						Part of Pillikin mine.
	Cowell	E. F. Glenn, et al., Folsom	4?	9N	9E	MD	Three miles east of Clarksville. Active during World War I when four carloads of chromite were produced. (Bradley and others 18:133; Cater and others 51:125-126.)
6	Darrington (Gurney)	George Darrington, Folsom	33	11N	8E	MD	(Allen 41:38; Averill 43:317-318; 556-557; Cater and others 51:150-151; herein.)
	Dickson	E. F. Glenn, et al., Folsom	4	9N	9E	MD	Three miles east of Clarksville. Northwest-trending chromite pods in dunite were mined in an open cut. (Cater and others 51:125.)
7	Dobbas	D. J. Dobbas, Auburn	22	11N	8E	MD	(Allen 41:139; Cater and others 51:146-148; herein.)
	Donnelly		21	11N	8E	MD	Part of Pilliken mine. (Bradley and others 18:133.)

CHROMITE (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Ever	Not determined	32	9N	9E	MD	Near Cothrin Station. Prospected in 1918. Small streaks and lenses of chromite strike north, occur in 100-ft. zone. (Cater and others 51:125.)
	Expansion						See Swortfiguer.
	Forni	Not determined		8N	10E	MD	Four miles east of Latrobe. One ton of ore produced in 1918. (Bradley and others 18:133; Cater and others 51:125.)
	Freeman	I. Ellingham and Erwin W. Vogel, c/o County Courthouse, Placerville	13	8N	9E	MD	Four miles southeast of Latrobe. In 1918, 40 tons of ore produced from north-striking chromite lens in serpentine. Developed by open cut. (Bradley and others 18:133-134; Cater and others 51:122.)
	Glenn	Willard C. Egloff, et al., Box 506, Folsom	14	8N	9E	MD	Adjoining Murphy mine. Prospected in 1918. (Bradley and others 18:134.)
	Gold Bug	Theresa Garibaldi, Amador City	19	8N	10E	MD	Four miles southeast of Latrobe on ridge east of Big Canyon Creek. Active in 1918 when 16 tons of chromite produced. A northwest -striking, 1- to 3-ft. zone of low-grade ore, 125 feet long. Developed by open cuts. (Cater and others 51:121.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Gordon	N.P. and Camilia Runge Route 2, Box 251, Placerville	13	10N	9E	MD	Four miles north of Shingle Springs. In 1918, 31 tons of chromite produced from float. (Cater and others 51:153.)
	Granite Bar						See Hoosier Gulch Placers. (Cater and others 51:148.)
8	Green	Not determined	19	13N	11E	MD	One and one-half miles south of Volcanoville near Otter Creek. Worked originally for gold. Active 1917-18 when more than 110 tons chromite produced and 1942 when 64 tons produced. A chromite lens up to 7 feet wide developed by 350-ft. adit, 40-ft. shaft, and raises and crosscuts. (Bradley and others 18:134-135; Cater and others 51:162-163.)
	Green claim	Not determined	24	12N	10E	MD	Two miles southeast of Georgetown. Active 1918 when 17 tons of 51% Cr_2O_3 ore produced. Pods strike northwest. Developed by 15 ft. shaft and drift. (Cater and others 51:161.)
	Gurney						See Darrington.
	Hector Williamson						See Williamson.
9	Helemar	Theresa Garibaldi, Amador City	30	8N	10E	MD	Five miles southwest of Latrobe. Active 1944-45 when 57 tons of ore containing 38% Cr_2O_3 produced. (Cater and others 51:121.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Henser	Not determined	14	12N	10E	MD	Two miles southeast of Georgetown. In 1918, 13 tons of chromite produced. (Cater and others 51:161.)
	Hill-Top Chrome	Not determined	18	13N	11E	MD	One mile southwest of Volcanoville. In 1918, 7 tons ore produced. Developed by 22-ft. shaft. (Cater and others 51:163.)
10	Hoff	Theresa Garibaldi, Amador City	30	8N	10E	MD	Five miles southeast of Latrobe. Active World War I when 107 tons 28 to 33% Cr_2O_3 ore produced. A. northwest-striking chromite lens 60 ft. long in sheared serpentine developed by open cut. (Bradley and others 18:135-136; Cater and others 51:120-121.)
	Hoosier Gulch Placers (Granite Bar)	Hoosier Gulch Placers, Sacramento	20	11N	8E	MD	Chromite-bearing river gravel at Granite Bar on American River near Pillikin mine mined in 1942 with dragline. (Cater and others 51:148.)
	Irish	Not determined	20	10N	10E	MD	Two and one-half miles east of Rescue. In 1918, 18 tons ore produced. Small chromite pods and stringers developed by open cuts. (Bradley and others 18:136; Cater and others 51:153.)
11	Joerger	Bertha J. Burton, 1115 Yale, Fresno	35	10N	8E	MD	(Bradley and others 18:136; Averill 43:140; Cater and others 51:126; herein.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Kelly	United States of America (withdrawn for Federal reservoir site).	16	11N	8E	MD	Just east of Rattlesmake Bridge. Active in 1918 when 25 tons 28% ore produced. (Bradley and others 18:136.)
12	Knoff (Austin)	W. B. and W. E. LaDue, 2319 "O" Street, Sacramento	25	13N	10E		Three miles northeast of Georgetown on Little Bald Mountain. Active 1918 when 400 tons of ore mined, and 1942-44 when 79 tons mined. Pods and lenses of chromite in sheared serpentine strike northwest. Developed by open cuts and shallow shafts. (Bradley and others 18:131; Cater and others 51:162.)
	Laicey	Not determined	32	12N	10E	MD	One and three-quarters miles west of Garden Valley. Small chromite pods in serpentine and talc. Developed by open cuts. (Cater and others 51:159.)
	McCurdy	Rolland Armstrong, 1291 Crow Canyon Road, Hayward	8	11N	10E	MD	Two miles north of Coloma. Active 1918 when 200 tons of ore containing 36% Cr_2O_3 produced. Two groups of northeast-striking chromite lenses in serpentine and talc. Developed by open cuts and 45-ft. shaft. (Bradley and others 18:136; Cater and others 51:155-156.)
13	McDonald and Buys	Nick J. Schubin, et al., Route 2, Box 216, Placerville	6	10N	10E	MD	One mile south of Four Corners. Active 1918 when 350 tons of chromite produced. Chromite pods strike north. Developed by three shafts and open pit. (Cater and others 51:154.)
	Miller	Joseph H. Miller, P.O. Box 282, Folsom	35	10N	8E	MD	One and one-half miles northwest of Clarksville, near Walker mine. Small amounts of layered chromite. (Cater and others 51:128.)

CHROMITE (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
15	Murphy	Willard C. Egloff, Box 506, Folsom	14	8N	9E	MD	(Bradley and others 18:136-137; Cater and others 51:123-124; herein.)
	Nielson						Part of Pillikin mine.
	Noble Electric Steel Company						Operated chrome mill one mile southwest of Salmon Falls during World War I. Ore was crushed, fine-ground, and concentrated on Wilfley tables and Senn concentrator. (Bradley and others 18:137.)
16	O'Brien (S-Bend)	C. F. Gladwill, 381 Acacia Street, Vacaville	6	11N	10E	MD	Two miles north of Coloma west of Perry Creek. Active 1918 when several hundred tons of ore produced, and 1942 when 3,000 tons produced and treated at Volo Mill at Shingle Springs. Lens of chromite up to 20 feet wide in dunite. Developed by two adits and glory hole. (Cater and others 51:126.)
	Ogle	Not determined	18	13N	11E	MD	One mile south of Volcanoville. Active 1917 when 47 tons of 45 percent ore produced. North-striking chromite lenses in serpentine. Developed by open cut. (Bradley and others 18:137; Cater and others 51:163, 166.)
17	Pfeiffer	W. J. Varozza, Shingle Springs	7	8N	10E	MD	Three miles east of Latrobe west of Big Canyon Creek. Active 1918 when 80 tons of chromite produced; prospected in 1942. Chromite pods trend northeast. Developed by open cuts. (Bradley and others 18:140; Carter and others 51:22.)
	Pilliken						See Pillikin.

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
18	Pillikin (Pilliken. Also includes Bonanza King, Chrome Gulch, Donnelly, Nielson, and Steele.)	American Trust Co., 464 California Street, San Francisco	21 28	11N	8E	MD	(Lindgren 94:3; Tucker 19:274,275; Bradley and others 18:137-140, 141-143; Logan 20:431-432; 26:404; 38:207,212; Allen 41:136-138; Averill 43:72; Cater and others 51:131-146; herein.)
19	Pilot Hill	W. J. Rogers, Route 3, Box 1340, Modesto	12	11N	8E	MD	Just west of Pilot Hill summit. Active in 1916 when 200 tons ore produced. Lenticular ore body in dunite strikes northeast. Developed by open cut. (Bradley and others 18:140-141; Allen 41:135-136; Cater and others 51:154-155.)
	Placer Chrome Company						Worked Pillikin mine during World War I; see Pillikin mine herein.
	Ruby Consolidated	Not determined	17,18 19	13N	11E	MD	One mile south of Volcanoville. A gold and chrome mine. During World War I, three carloads chromite containing 46 percent Cr_2O_3 shipped. See also gold tabulated list.
	S-Bend						See O'Brien.
20	Shelly (Wolf)	J. A. Wolf, Garden Valley	5	11N	10E	MD	Two miles southwest of Garden Valley. Active 1918 when 1,284 tons of ore containing 30 percent Cr_2O_3 were mined. Irregular lenses of chromite in serpentinized dunite trend north. Developed by open pit and shaft. (Bradley and others 18:143; Cater and others 51:158.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Sheppard	Not determined	32	12N	10E	MD	Two miles west of Garden Valley. Active World War I when more than 50 tons of 35 percent Cr_2O_3 ore produced. North-trending chromite lenses in serpentine. Developed by open cuts and shafts. (Cater and others 51:159-160.)
	Simon	C. F. Gladwill, 381 Acacia Street, Vacaville	5	11N	10E	MD	Two miles southwest of Garden Valley. Active 1918, 1920 94 tons 35 percent Cr_2O_3 ore produced. Northeast-trending chromite lenses in serpentinized dunite. Developed by open cuts. (Cater and others 51:156-158.)
21	Simpson	Not determined	13	10N	8E	MD	Five miles north of Clarksville. Active in 1917 when 54 tons ore produced. Lenticular chromite bodies striking north near serpentine-schist contact. Developed by open cuts and shallow shafts. (Bradley and others 18:143; Cater and others 51:128.)
	Smith	George A. Smith et al., Box 66, Folsom	9	8N	9E	MD	Three-quarters of a mile northwest of Latrobe. Northwest-striking chromite lens in serpentine and talc mined from 100-ft. open cut. (Cater and others 51:124-125.)
	Southeastern Railroad	United States of America (withdrawn for Federal reservoir site.)	21	11N	8E	MD	One mile north of Pillikin mine. Zones of small chromite pods developed by open pits and adits. (Allen 41:138.)
22	Stafford	Ethel S. Hughes et al., R.F.D. #1, Box 568, Carmel	36	13N	10E	MD	Two miles northeast of Georgetown. Active 1918 when 198 tons ore produced and 1942-43 when a few tons produced. Irregular north-striking chromite lenses and pods mined in open cuts. (Cater and others 51:161-162.)
	Steele		28	11N	8E	MD	See Pillikin mine.

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Stifle	Not determined	25	12N	10E	MD	Three miles northwest of Garden Valley. Active 1918 when 4 tons 35 percent ore produced. Small chromite pods in serpentine and talc developed by open cuts. (Bradley and others 18:143; Cater and others 51:160-161.)
	Swortfiguer (Expansion)	George B. and Helen Swortfiguer, 804-48th Street, Sacramento	17,18	10N	10E	MD	Four miles northeast of Shingle Springs. Active 1914-18 when 80 tons ore produced; prospected in 1943. Developed by open cut. (Averill 43:72.)
	Taylor						See Darrington.
	Thomas and Meldrum	Not determined	18	10N	10E	MD	Two miles east of Rescue. During World War I, one carload ore produced from small stringers and pods in serpentine. Developed by two shafts. (Cater and others 51:153.)
	Trio Chrome Company						During World War I, leased Hoff and Helemar properties and placer mined chromite-bearing gravel near Cosumnes River in sec. 25, T. 8 N., R. 9 E. (Cater and others 51:121.)
	Tropper	Not determined	32	12N	10E	MD	One and one-half miles west of Garden Valley. Active 1918 when 110 tons ore mined. Lens 10-ft. long developed by 40-ft. inclined shaft. (Bradley and others 18:143-144.)

CHROMITE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Veerkamp	Ray A. Veerkamp, Garden Valley	33	12N	10E	MD	One and one-half miles southwest of Garden Valley. Active 1916 when 38 tons ore containing 41 percent Cr_2O_3 mined. Number of small northwest-striking chromite pods developed by open pits. (Cater and others 51:158-159.)
23	Walker	Faustino Silva, Route 8, Box 951, Sacramento	35	10N	8E	MD	(Cater and others 51:126-128; herein.)
	Wiley	Not determined	1	10N	9E	MD	One mile southwest of Four Corners. Active 1916 when 45 tons chromite produced from open cuts. (Bradley and others 18:144; Cater and others 51:154.)
24	Williamson	George Williamson et al., Route 2, Box 288, Placerville	7	10N	10E	MD	Six miles due north of Shingle Springs. Active 1918 when 55 tons ore containing 40 percent Cr_2O_3 produced. Irregular chromite pods in slickentite. (Cater and others 51:154.)
	Williamson (Hector Williamson)	Not determined	7	10N	10E	MD	Possibly same as above, though production of only 40 tons reported. (Cater and others 51:153.)
	Wilson	Not determined	23	12N	10E	MD	Two miles northwest of Garden Valley. Shipping and milling-grade ore produced 1943. (Averill 43:72.)
	Wolf						See Shelly.
	Zanini	Not determined	35	9N	9E	MD	Two miles northeast of Latrobe. Low-grade deposit prospected during World War I. (Bradley and others 18:144.)

COPPER

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Agara	Clifford Smith, Somerset	24	9N	12E	MD	Three miles northeast of Fairplay and just north of Consumnes copper mine. Developed by 25-ft. shaft. (Aubury 02:180; 08:216; Eric 48:228.)
25	Alabaster Cave	United States of America (withdrawn for Federal reservoir site)	10,15	11N	8E	MD	One mile east of Rattlesnake Bridge. Active prior to 1902. A north-striking 8-ft. copper-bearing zone dips east with limestone hanging and slate footwall. Contains 3 to 4 percent copper and some gold and silver. Developed by 300- and two 50-ft. shafts and 100- and 30-ft. adits. (Aubury 05:176; Heyl and others 48:228; Aubury 08:211-212; Tucker 19:276.)
	Arizona	Not determined	24	12N	10E	MD	Two miles southeast of Georgetown. Copper claim containing gossan outcrops as much as 100 ft. wide. (Aubury 05:180; 08:216; Eric 48:228.)
	Barklage and Miller	William Barklage et al., 5713 State Avenue, Sacramentc	13	12N	10E	MD	Two miles southeast of Georgetown. Active 1908. Gossan capping 100 ft. wide in slate. Developed by 118-ft. adit. (Aubury 05:178; 08:214; Eric 48:228.)
26	Big Buzzard (Hercules, Darrington)	George Darrington, Folsom	29	11N	8E	MD	(Logan 21:430; 23a:209; 23b:141,142; 26:406,412; Averill 43:72; herein.)
	Blue Cat (Madelina, Madeline, Magdalena)	George Fausel, Placerville	18	9N	11E	MD	Five miles south of Diamond Springs; south extension of Noonday mine. Active prior to 1900. Zone 40 tc 60 ft. wide in metasediments contains pyrrhotite, chalcopyrite, and pyrite with gold. Developed by 90-ft. cross-

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Blue Cat (continued)						cut adit, 100-ft. crosscut adit, 100-ft. drift, and 105-ft. shaft. (Storms 00:91; Eric 48:228.)
	Bob						See Iron Crown.
27	Boston	Not determined	22	9N	9E	MD	Four miles southwest of Shingle Springs. Active 1860's and 1870's when good ore was produced. Country rock schist. Developed by 400-ft. shaft. (Aubury 05:180; 08:216; Eric 48:229.)
28	Breala	Not determined	2	8N	9E	MD	Two miles northeast of Latrobe. Old shaft reopened in 1917 and some 4½ percent Cu ore mined. Developed by 70-ft. shaft. (Logan 26:407; Eric 48:229.)
	Bryant Ranch	Not determined	2	8N	9E	MD	One and one-half miles northeast of Latrobe. Active 1860. A 4-ft. vein containing copper oxide and carbonates. Developed by 64-ft. shaft. (Aubury 05: 180; 08:216-217; Eric 48:229.)
	Bunker Hill	E. A. Long et al., Renobscot Farm, Cool	14	12N	9E	MD	Two miles southwest of Greenwood. Active 1860's. Developed by 60-ft. shaft. (Aubury 05:181.)
29	Cambrian	L. D. Stodick, et al., Lotus	23	11N	9E	MD	Three miles west of Coloma. Active 1850's, 1900, 1908. Three veins of talcose schist between granodiorite and serpentine contain chalcopyrite, malachite, native copper and gold. Ore contains up to 10 percent

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
							copper. Developed by 113-, 220-, and 1360-ft. adits, winzes and drifts. (Aubury 05:177-178; 08:213-214, 218; Tucker 19:276-277; Eric 48:229.)
30	Camelback (Voss)	Aleta V. Coulet, 215 Market Street, San Francisco	11	11N	8E	MD	Three miles southwest of Pilot Hill on Burner Hill. Active around 1920. A massive quartz vein strikes northeast, dips northwest, and contains chalcopyrite, pyrite, and some bornite. Developed by 25-ft. shaft, 123-ft. drift adit, 165-ft. crosscut adit. A parallel vein half a mile east developed by 200-ft. and 40-ft. shafts. (Logan 20:430-431; 26:407; Eric 48:229.)
31	Contraband (Ford)	Not determined	24	12N	10E	MD	Two miles southeast of Georgetown. Active 1860, 1902, 1910. A 12-ft. vein striking north 80° east and dipping 45° northwest in schist contains native copper and copper sulfides. Also an asbestos property (see section on asbestos). (Aubury 05:178; 08:214-216; Tucker 19:277; Eric 28:229.)
	Copper Chief	Not determined	12	12N	10E	MD	Two miles east of Georgetown. Gossan outcrops 100 to 200 ft. wide. (Aubury 05:180; 08:216; Eric 48:229.)
	Costa Ranch	F. J.Costa, Jr., Pilot Hill	12	11N	8E	MD	Two miles southwest of Pilot Hill. North-striking east-dipping vein contains malachite, chalcopyrite, and pyrite. Developed by 60-ft. vertical shaft and open cuts. (Aubury 08:218; Eric 48:229.)
32	Cosumnes	Clifford Smith, Somerset	24,25	9N	12E	MD	(Crawford 96:58; Aubury 05:178; 08:214,215; Tucker 19:277; Eric 48:229; herein.)

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Cothrin	Not determined	29	9N	9E	MD	Near Cothrin Station. Prospected 1926. Massive pyrite with chalcopyrite in amphibolite. Developed by 100-ft. shaft. (Logan 26:407; Eric 48:229.)
	Darrington						See Big Buzzard.
	Diamond Springs						See Larkin in Lode gold section.
	Dr. Wren	C. Padilla, El Dorado	7	9N	11E	MD	Three miles southeast of El Dorado and east of the Mother Lode. A 6-ft. vein of talcose schist contains 5 to 18 percent copper. Developed by 18-ft. shaft. (Aubury 05:180; 08:216; Eric 48:229.)
	Dodson						See Rip and Tear.
33	E. E. Copper	Not determined	18	9N	11E	MD	Four miles southeast of El Dorado. Active around 1914. A 2-ft. north-striking and east-dipping vein in metadiabase contains bornite, chalcopyrite, pyrite, gold, and silver. Developed by 85-ft. vertical shaft, with 300 ft. of drifts and 100- and 300-ft. adits. (Aubury 08:218-219; Tucker 19:277; Eric 48:230.)
34	El Dorado (Roosevelt)	Calivada Development Company, Box 4, Garden Valley	34	12N	10E	MD	(Bedford 46; Eric 48:230; herein.)
	Ford						See Contraband.

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Funny Bug	R. V. Montgomery, Route 2, Box 193-K, Placerville	4	10N	10E	MD	Gold mine containing some copper; see Lode gold section. (Logan 38:242-243; Eric 48:230.)
	Hale	Clifford Smith et al., Somerset	25	9N	12E	MD	South extension of Cosumnes mine. (Aubury 08:217; Eric 48:230.)
	Hercules						See Big Buzzard.
	Homestead	Not determined		12N	9E	MD	Three miles west of Greenwood. A 14-ft. vein contains copper and gold. (Aubury 05:177; 08:213; Eric 48:230.)
	Irland	Not determined	15	10N	10E	MD	Three miles west of Placerville. Active 1866, 1906. Vein in granodiorite strikes north, dips east, contains chalcopyrite. Ore contained 2 percent copper, some gold and silver. Developed by 75-ft. vertical shaft and 18-ft. drift. (Aubury 08:218; Eric 48:230.)
35	Iron Crown (Bob)	Not determined	13	12N	10E	MD	One mile southeast of Georgetown. Active prior to 1902 and again around 1908. A series of gossan cappings and copper-bearing veins with slate and serpentine walls; extends south to Contraband mine. Water is copper-bearing. Developed by 75-ft. shaft and open cuts. (Aubury 05:181-182; 09:219-220; Tucker 19:276; Eric 48:230.)

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Larkin (Diamond Springs)		29	10N	11E	MD	Gold mine containing some copper; see section on Lode gold.
	Lilyama (Little Emma, Volo)						See Pioneer-Lilyama.
	Little Emma						See Pioneer-Lilyama. (Aubury 08:212; Logan 26:408.)
	Longshot	Leslie Fry and Clifford Smith, Somerset	26	9N	12E	MD	One mile west of Cosumnes copper mine. Prospect that is worked intermittently. Copper stains in granite and metasediments. Developed by 200-ft. adit.
	Madelina						See Blue Cat.
	Madeline						See Blue Cat.
	Magdalena						See Blue Cat.
36	Noonday	George Fausel, Placerville	18	9N	11E	MD	(Aubury 02:182; 08:220; Tucker 19:278; Eric 48:231; herein.)
37	Pioneer-Lilyama (Little Emma, Volo)	H.H. Mitchel 9490 Brighton Way, Beverly Hills; Leased by Wilcox-Lilyama Mining Co., F.L. Wicks, Manager	3	11N	9E	MD	(Aubury 02:176-177; 08:212-213, 218; Tucker 19:277-278; Averill 43:140; Cox and others 48:43-47; Eric 48:231; herein.)
	Revoir	Not determined	12	9N	12E	MD	Two miles southeast of Pilot Hill. Copper prospect south of Costa Ranch mine. (Aubury 08:217; Eric 48:231.)

COPPER (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
38	Rip and Tear (Dodson)	Fred H. Dodson, 2404 - 26th Street, Sacramento	3	8N	9E	MD	(Aubury 02:181; 08:219; Logan 26:408; Averill 43:140; Eric 48:231; herein.)
39	Robert	Robert L. Cameron et al., 1217 Del Paso Blvd., North Sacramento	13	9N	11E	MD	Two miles northeast of Outingdale. A 3½-ft. vein in schist and slate; ore yielded 4 to 24 percent copper. Developed by 80-ft. shaft and 150-ft. crosscut adit. (Aubury 05:180-181; 08:216-217; Tucker 19:278; Eric 48:232.)
	Roosevelt						See El Dorado.
	Seven Bells (Sporting Boy)	Not determined	10	10N	10E	MD	Four miles west of Placerville. Prospected 1917 and 1918. Vein up to 18 inches wide contains copper and gold Developed by 65-ft. shaft. (Logan 26:408; Eric 48:232.)
	Sporting Boy						See Seven Bells.
	Volo						See Pioneer-Lilyama and Volo mill.
	Volo Mill	Volo Mining Company, 464 Main Street, Placerville	21	10N	10E	MD	Also see Shaw mine in Lode gold section. (Averill 43:140; herein.)
	Voss						See Camelback.
	Woods	George [illegible]. Smith et al., Box 66 Folsom	4	8N	9E	MD	One mile northwest of Latrobe. A 5-ft. vein in schist contains copper. Developed by 12-ft. shaft. (Aubury 05:181; 08:219; Eric 48:232.)

LODE GOLD

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
40	Adams Gulch (Stony Point, Sullivan)	Camilla D. Head, 624 South 13th St., San Jose	25,26	9N	10E	MD	On Mother Lode two miles northeast of Nashville. Active 1902-11, when $9,482 was produced, and again in 1914. A 4-ft. vein in slate strikes north 10° west and 60° east. Developed by 180- and 200-ft. crosscut adits. (Crawford 94:101; 96:132; Tucker 19:279; Logan 34:15.)
41	Adjuster (Hustler)	Cecilia Simpson, 4029 Kuhnle Street, Oakland	12	9N	10E	MD	On Mother Lode two miles southwest of El Dorado. Active prior to 1914. A 5-ft. vein in slate. Developed by 250-ft. crosscut adit and about 100 feet of drifts. A 10-stamp mill on property. (Tucker 19:280; Logan 34:15.)
42	Alhambra	Wilber E. Timm et al., c/o County Court House, Placerville Leased by Alhambra-Shumway Mines Inc., 681 Market Street, San Francisco Sub-leased to Alhambra Gold Mine Corporation, 1930 Outpost Drive, Hollywood	6,7	11N	11E	MD	(DeGroot 90:178; Logan 35:22; 38:216; Bowen and Crippen 48:70; herein.)
43	Alpine (Union Consolidated)	Elizabeth F. Burks, 4240 12th Street Sacramento	15,16	12N	10E	MD	(Irelan 88:167-168; Crawford 96:132; Tucker 19:280; Logan 34:15-17; Bowen and Crippen 48:70; herein.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	Artic	Not determined	20	9N	13E	MD	Two miles southwest of Grizzly Flat. Long idle.
	Argonaut (Aultman, Golden Unit)	El Dorado Argonaut Mines, c/o J. A. Sisler, Box 527, Visalia	17	12N	10E	MD	On **Mother** Lode $1\frac{1}{2}$ miles southeast of Greenwood. Active 1880's, 1921, and 1927-28. A northwest striking vein up to 15 ft. wide developed by drift adit. Ore yielded up to $15 per ton. Ore first treated in 10-stamp mill and later in a Gibson mill. (Irelan 88:176; DeGroot 90:176; Crawford 94:101; 96:132; Tucker 19:280; Hamilton 22:29; Logan 22:209; 26:413-414; 34:17.)
44	Argonaut Fraction	Pete Lopez, 4833 - 9th Avenue, Sacramento	17	12N	10E	MD	(Herein.)
	Armstrong	Not determined	28	9N	13E	MD	Two and one-half miles south of Grizzly Flat. Prospected in 1920. North-and east-striking veins in granodiorite. Developed by 100- and 114-ft. shafts and 180-ft. drift. (Logan 20:425-426.)
	Asbestos						See Brust.
	Aultman						See Argonaut.
	Bald Eagle						See Crown Point Consolidated.
	Baldwin						See Briarcliffe. (Crawford 94:102, 96:133; Tucker 19:280.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
45	Balmaceda	Camilla D. Heald, 624 South 13th Street, San Jose	35	9N	10E	MD	One and one-half miles northeast of Nashville. Active in 1914. Two parallel 4-ft. veins in Mariposa slate strike north 20° east and dip 65° east; ore shoots were 40 to 100 feet long. Developed by 500-ft. drift adit on west vein; stoped to surface. (Tucker 19:280-281.)
46	Baltic	Oscar E. Reeg, 12 Mill Street, Placerville	23	10N	13E	MD	Five miles north of Grizzly Flat on north side of Baltic Peak. Active in 1896 and 1907. A 1-ft. vein in slate strikes northeast and dips 50° East. Developed by 500-ft. drift adit and 130-ft. inclined shaft. Ore treated in 10-stamp mill. (Crawford 96:133; Tucker 19:280.)
47	Barnes-Eureka (Greenstone)	B. F. Baskin, Sr., Route 2, Box 38, Placerville	28 33	10N	10E	MD	(Crawford 94:102,112; 96:144; Tucker 19:281; Logan 38:217; herein.)
	Base Bonanza	Not determined	32	12N	10E	MD	One mile west of Garden Valley. Active prior to 1894. Diorite is east and serpentine is west of vein. (Crawford 94:102.)
	Bathurst						See Coe Hill.
48	Beebe (Brooklyn, East Lode, Iowa, Woodside-Eureka)	Woodside-Eureka Mining Co., Ltd., c/o T. B. Meyers, 1605 Tribune Tower, Oakland 12	2,3, 11	12N	10E	MD	(Logan 34:17-19, 207-211; 38:217-218; Bowen and Crippen 48:70; herein.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Bell						See River Hill group.
	Berg						See Blue Gouge.
	Berry						See Placerville Gold Mining Company.
49	Bidstrup	Walter Bidstrup, Box 35, El Dorado	11	9N	10E	MD	Two miles south of El Dorado. A 1-ft. north-striking vein in granodiorite. Developed by 35-ft. shaft and 100-ft. adit. (Crawford 94:103; 96:133; Tucker 19:281.)
	Big Buzzard						Copper mine containing some gold; see copper section.
50	Big Canyon (Oro Fino)	Capital Company, 1 Powell Street, San Francisco 2	29	9N	10E	MD	(Irelan 88:174-175; Crawford 94:103-104; 96:133; Tucker 19:293; Logan 22:209; 26:412; Huttl 35b:216-219; Logan 35:22; 38:220-223; herein.)
51	Big Chunk	T. C. Smith, Jr., 100 Canal Street, Placerville	24	11N	10E	MD	Half mile east of Kelsey. A 3-ft. vein in hanging wall of Mother Lode. Developed by 100-ft. shaft and 150-ft. adit. (Tucker 19:281; Logan 34:19.)
	Big Four (Golden Oak)	Not determined	34	12N	10E	MD	On Mother Lode one mile southeast of Garden Valley. Active during 1890's; prospected in 1940. A 30-inch vein in slate strikes north 10 west and dips 55° east. Ore yielded $10 to $13 per ton. Developed by 96-ft. inclined shaft and 100-ft. drift. (Tucker 19:281; Logan 34:19.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Big Jim (Phillips)	Not determined		8N	8E	MD	Two and one-half miles southwest of Latrobe. Active around 1896. A north-trending vein with gouge lies between slate and diabase. Developed by shaft and 240-ft. crosscut adit. Ore treated in 2-stamp mill. (Crawford 96:134-135.)
52	Big Sandy (James Marshall)	H. J. Picchetti, 1115 Fairview Avenue, San Jose	24	11N	10E	MD	(DeGroot 90:173-174; Crawford 94:104; 96:134; Tucker 19:281; Logan 34:19-20; herein.)
	Black Hawk	H. J. Picchetti, 1115 Fairview Avenue, San Jose	24	11N	10E	MD	On Mother Lode 3/4-mile south of Kelsey. A 4-ft. vein in slate. Developed by 200-ft. drift adit. (Tucker 19:281.)
53	Black Oak (Clark, Davey, Dayton Consolidated)	Russell J. Wilson Garden Valley	27,34	12N	10E	MD	(Logan 34:20-21; 38:223-224; Bowen and Crippen 48:70; herein.)
	Black Lead	Not determined					Six miles south of Shingle Springs. Active prior to 1894. Quartz vein is black in appearance. (Crawford 94:104; 96:134.)
	Blue Bank	Not determined		11N	9E	MD	Nine miles northwest of Shingle Springs. Active in 1896. A $1\frac{1}{2}$-ft. vein in amphibolite strikes north and dips 74° W. Developed by 120-ft. drift adit, 100-ft. inclined winze, and open cuts. Ore was treated in 2-stamp mill. (Crawford 96:134; Tucker 19:281.)
54	Blue Gouge (Berg)	Americo & Columbus Sciaroni, Grizzly Flat	21	10N	13E	MD	(Crawford 96:135; Logan 38:224-225; herein.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Blue Lead	Helen B. King, 20 Molly Lane, Placerville	3	11N	10E	MD	On Mother Lode one and one-half miles southeast of Garden Valley. Active around 1867. Specimen ore produced. Ore treated in 20-stamp mill. (Logan 34:21.)
	Board						See Bordt.
	Bollhalter	Not determined	1	10N	9E	MD	One mile south of Four Corners. Assays from large quartz outcrop in amphibolite near serpentine body were $1.40 to $3.80 per ton. (Logan 38:225.)
	Bona Forsa	Not determined		11N	10E	MD	Northwest of Placerville. Active around 1890. Two north-striking veins rich in sulfides. Developed by 50- and 65-ft. shafts and crosscuts. (DeGroot 90:177.)
55	Bonanza	Camilla D. Heald, 624 S. 13th Street, San Jose	11	8N	10E	MD	On Mother Lode 1 mile south of Nashville. Active 1922. Ore treated in 5-stamp mill. (Logan 23a:44.)
56	Boneset	Mrs. W. Moore, 1120 - 24th Street, Sacramento	10,11	10N	9E	MD	Three miles northwest of Rescue. Active in 1894; intermittently active in 1930's with a small production. A 10- to 15-ft. vein in metadiorite and greenstone strikes northeast and dips 70° northwest; free gold is in thin bands with pyrite, chalcopyrite, and galena. Developed by 140-ft. crosscut adit and several hundred feet of drifts and open cuts. (Crawford 94:104; 96:135; Tucker 19:282.)
	Bordt (Board)	Not determined	7	12N	10E	MD	Half a mile east of Greenwood. Active in 1894 and 1926.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Bordt (continued)						A 4-ft. west-striking, north-dipping vein in slate. Developed by a 60-ft. drift adit. (Crawford 94:104; 96:135; Tucker 19:282.)
57	Boulder (Kaeser)	Not determined	32	11N	9E	MD	Five miles northwest of Rescue. Active in 1896; some activity in 1931 and 1934. A 7- to 8-ft. vein in granodiorite strikes northeast and dips 35° northwest. Developed by four adits, one a 400-ft. crosscut; extensive drifting. Ore was treated in a 10-stamp mill. (Crawford 96:135-136; Tucker 19:282; Logan 35:22; 38:234-235.)
	Brandon	Not determined	31	9N	10E	MD	Three and one-half miles northeast of Latrobe. Active many years ago. A north-trending body of greenstone containing disseminated auriferous pyrite; developed by shaft and adit.
58	Bret Harte (Safeguard No. 1)	Not determined	6	11N	12E	MD	On north slope of Slate Mountain four miles southwest of Pino Grande. Active around 1934 when several hundred tons of ore were mined from surface. There are two veins, one developed by 240-ft. adit and the other by a 50-ft. adit. (Logan 38:225.)
59	Briarcliffe (Baldwin, Last Chance)	Nick Neilsen, Box 100, Diamond Springs	1,2, 11,12	8N	10E	MD	(Crawford 94:102; 96:133; Tucker 19:280; Logan 38:226; herein.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
60	Bright Hope	Hope Oehm, 24-A Second Street, Woodland	2	12N	10E	MD	One mile northeast of Georgetown. Active in 1890 and 1896. A 6-ft. vein in Mariposa slate strikes northeast and dips 35° northwest. Developed by 400-ft. crosscut adit and 80-ft. shaft. (De Groot 90:177; Crawford 94:105; 96:136; Tucker 19:282.)
	Brooklyn		2,3	12N	10E	MD	See Beebe.
	Brown Bear		36	11N	10E	MD	See Placerville Gold Mining Company. (Irelan 88:182.)
61	Brust (Asbestos, Gold Hill)	William Hodge, c/o Margaret Hodge Rains, 932 Fresno Avenue, Berkeley 7	6	11N	11E	MD	One mile northeast of Spanish Flat. Active in 1926. Free gold is in calcite, quartz, and talc stringers in serpentine. Developed by several shallow shafts and 800-ft. adit. (Logan 23a:44; 26:412.)
62	Buena Vista	Blanch Schuster, P.O. Box 43, El Dorado	13,24	9N	10E	MD	On Mother Lode three miles southeast of El Dorado. Active around 1900; prospected 1936 and 1940-42 with very little production. Several veins are in schist. Developed by 208-ft. shaft with 400 ft. of drifts and 250-ft. adit. (Storms 00:91; Logan 38:227.)
	Bullard						See Golden Trace.
	Calaveras	Not determined		8N	10E	MD	Four miles east of Latrobe. Active in 1896. A northeast-striking vein in slate and greenstone; contains free gold and auriferous sulfides. Developed by 32- and 53-ft. shafts and open cuts. (Crawford 96:136.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
63	Caledonia	Wayne Huckaby, Garden Valley	15	11N	10E	MD	Two miles west of Kelsey. Active around 1900; prospected in 1948-49 but no production. A 5-ft. vein contains auriferous pyrite. Developed by shaft.
64	California Consolidated (Ibid, Tapioca)	Albert N. Brown et al., 5252 James Avenue, Oakland	16	9N	13E	MD	One mile southwest of Grizzly Flat. Active in 1896; reopened in 1938. Several veins in mica schist including the Tapioca which strikes north 6° east, and dips northwest. Tapioca vein yielded ore containing $11.30 per ton. Developed by 468- and 70-ft. crosscut adits. Ore was treated at Morey mill. (Crawford 96: 159; Logan 26:412-413; 38:227-228.)
65	California Jack	Not determined	15,22	12N	10E	MD	Three miles southwest of Georgetown. Active prior to 1896. A 12-ft. vein in Mariposa slate strikes north and dips 60° E. Developed by 350-ft. crosscut adit, 200-ft. north drift, and 90-ft. shaft. Ore was treated in 10-stamp mill. (Crawford 96:136; Tucker 19:282.)
	Central						See Inez.
	Chanced Upon						See Darling.
66	Chaparral (Golden Queen)	P.C. Stingle, c/o Lynn, Woodworth, and Evarts, 75 Federal Street, Boston, Mass.	26	11N	10E	MD	On Mother Lode two miles southwest of Kelsey. Active 1872-75, and 1901. A 6-ft. vein strikes northwest and dips 70° east with diabase footwall and slate hanging wall. Ore yielded $7 to $15 per ton. Developed by 200-ft. shaft and 50-ft. adit. Ore was treated in mill on property. (Tucker 19:283; Logan 34:21.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Chester		18	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:182-183; DeGroot 90:173; Crawford 94:106.)
67	China Hill	E. J. Murray, Box 1282, Carmel	16	9N	10E	MD	Three miles southwest of El Dorado. Active prior to 1894. A 5-ft. vein in hornblende porphyry strikes north and dips 70° east. Ore is in small, rich shoots. Developed by 200-ft. crosscut adit, 200 ft. of drifts, and open cuts. Ore was treated in a 5-stamp mill. (Crawford 96:106; 96:137; Tucker 19:283.)
68	Church	Madre de Oro, Gold Mines Company, Box 925, Corcoran	12	9N	10E	MD	(Hanks 86:43; Irelan 88:191-193; DeGroot 90:171; Crawford 94:106; 96:137-138; Storms 00:92; Tucker 19:283; Logan 22:209; 26:413; 34:21-22; herein.)
	Cincinnati	Florence G. Kyle, Kelsey	3	11N	10E	MD	On Mother Lode, one and one-half miles southeast of Garden Valley. Active 1917-18. Gold occurs in stringer in decomposed dike in Mariposa slate. Ore yielded $3.82 per ton by amalgamation. Developed by open cuts and shallow shafts. Ore was treated in 5-stamp mill. (Logan 34:22.)
	Cinnamon Bear		36	11N	10E	MD	See Placerville Gold Mining Co. (Crawford 94:106; Irelan 88:182; Preston 93:201:)
	Clark						See Black Oak.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
69	Coe Hill (Bathurst, Gold Star)	Not determined	33	12N	10E	MD	On Mother Lode one mile south of Garden Valley. Active 1921, 1925-1926. Several veins yielded $6 to $20 per ton. Developed by shallow shafts and an adit. Ore was treated in a 2-stamp mill. (Logan 26:417; 34:22-23.)
	Collins and Bacchi	C. S. Collins, Box 231, Placerville	28	12N	10E	MD	Near Garden Valley. Prospected prior to 1914. (Tucker 19:283.)
70	Cosumnes (Melton, Middle End)	Caldor Lumber Company, Diamond Springs	4	9N	13E	MD	(Irelan 88:178-180; Crawford 94:117; 96:150; Tucker 19:291; Logan 26:418; 38:238; herein.
71	Cousin Jack	Martha Agnes Weber (3/4), Placerville and Maryland Casuality Company (1/4), 240 Sansome Street, San Francisco	29	9N	13E	MD	Five miles southwest of Grizzly Flat. Active prior to 1894. A 1- to 4-ft. vein in slate strikes north and dips 60° west. Developed by 400- and 300-ft. drift adits and 70-ft. winze. (Crawford 94:107; 96:138; Tucker 19:283.)
	Crescent						See Placerville Gold Mining Company.
72	Crown Point Consolidated (Bald Eagle, Gold Queen)	J. T. Richards Estate, Placerville	31	10N	11E	MD	On Mother Lode one and one-half miles southeast of Diamond Springs. Active 1894 and again around 1923. Three veins 4 to 20 ft. wide in Mariposa slate strike N. 27° E. and dip 72° east. Small lots of ore yielded $20 per ton or more. Developed by 500-ft. inclined shaft with 100-, 200-, 300-, and 400-ft. levels. A 600-ft. drain tunnel intersects shaft at 300-ft. level. A 150-ft. shaft south of main shaft. (Crawford 94:107; 96:138; Tucker 19:283-284; Logan 24:8; 34:23.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Crusader	Mary Ann Simpson, c/o J. P. Conroy, Box 212, El Dorado	12	9N	10E	MD	On Mother Lode two miles south of Diamond Springs. Active prior to 1914 and again in 1929. A 3-ft. vein in Mariposa slate strikes north 20° east and dips 80° west. Developed by 100-ft. inclined shaft with 100-ft. level. (Tucker 19:284.)
73	Crystal	W. L. and S. S. Lovejoy, Cool	18	12N	9E	MD	One-half mile north of Cool. Active in 1896; prospected in 1931. Vein in quartz prophyry strikes north and dips 15° west. Contains chalcopyrite. Developed by 25-ft. shaft and two 60-ft. inclines. (Crawford 96:138; Tucker 19:284.)
74	Crystal	Arthur S. Morey et al., 91 Ricon Way, San Francisco	32,33	9N	13E	MD	On Cosumnes River, five miles southeast of Grizzly Flat. Active around 1894. There are three nearly west-striking veins in granite with steep dips. Developed by 70- and 250-ft. shafts and 1200-ft. crosscut adit. Ore was treated in an 8-stamp mill. (Crawford 94:107; 96:138; Tucker 19:284.)
75	Crystal (El Dorado Crystal)	F. W. Barrette, Shingle Springs	18	9N	10E	MD	(DeGroot 90:178; Crawford 94:107-108; 96:138; Tucker 19:284; Logan 39:228-229; herein.)
76	Dailey and Bishop	Lucian Vaira, Drytown	27	9N	13E	MD	Two miles south of Grizzly Flat. Active around 1896. A $1\frac{1}{2}$- to 3-ft. vein in slate strikes north. Developed by 800-ft. drift adit, crosscuts, and winze. Ore was treated in a 10-stamp mill. (Crawford 94:108; 96:138-139; Tucker 19:284.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
77	Dalmatia (Kelly)	W.F.I. Bell Estate, c/o Jay R. Fogal, Box 100, Garden Valley	13	11N	10E	MD	Just east of Kelsey. Active 1880's, 1890-94 and again around 1935. Quartz seams and vein are in zone 20 to 50 ft. wide that strikes north 10° west and dips northeast. A 2-ft. vein contained $16 per ton; a pocket yielded $14,000; the seams yielded $2 to $3 per ton. Originally worked in open cut 500 ft. long. Developed by 200-ft. inclined shaft and 1200-ft. adit. Ore treated in Huntington mills and 10-stamp mill. (Irelan 88:177; DeGroot 90:174-175; Preston 92:201-202; Crawford 94:108; 96:139; Tucker 19:284; Logan 34:23.)
78	Darling (Chanced Upon)	E. V. Rhodes, Kelsey	33	12N	11E	MD	Four miles northeast of Spanish Flat. Active around 1892. A 2-ft. vein in slate strikes north and dips east and contains $5 to $6 per ton in free gold with calaverite and petzite. Developed by 190-ft. shaft. Ore was treated in 10-stamp mill with Frue concentrators. (Preston 92:202; Crawford 94:108; 96:139; Tucker 19:284.)
	Darrow						See Log Cabin.
	Davenport	Dudley G. Davenport et al., P.O. Box 33, Garden Valley	34	12N	10E	MD	On Mother Lode one-half mile east of Garden Valley. Active in 1934. Later, worked jointly with Black Oak Mine, which see. Gold occurs in amphibolite schist. Developed by 280-ft. crosscut adit and open cuts. (Logan 34:21.)
	Davey						See Black Oak.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
79	Davidson	Jerome M. Strickland et al., Route 2, Box 56, Placerville	22,27	10N	10E	MD	Two miles northwest of El Dorado. Originally active prior to 1894; prospected in 1947-48. A 2-ft. vein in slate strikes north 10° west and dips 74° northeast. Developed by 280-ft. inclined shaft with 100- and 300-ft.levels. Ore originally treated in 20-stamp mill and later in 5-stamp mill. (Crawford 94:108; 96:139; Tucker 19:284-285.)
	Dayton Consolidated						See Black Oak. (Logan 38:224,363.)
	Defiance	Not determined		10N	10E	MD	Five miles northeast Shingle Springs. Gold occurs in green schist. (Crawford 94:108.)
	Diamond						See Tullis.
	Diamond Springs						See Larkin.
	Donozo	Not determined		12N	10E	MD	One-half mile east of Greenwood. Vein strikes north 40° west and dips 55° northeast. Developed by 60-ft. drift adits. (Crawford 94:108; 96:139.)
	Duncan and Adams	Not determined	1,2	9N	10E	MD	One mile southeast of El Dorado. Active 1931 when 700 tons ore mined that yielded $10,266.
80	Eagle	Austin E. Borcham et al., Camp Seco	9	9N	13E	MD	One and one-half miles north of Grizzly Flat. Active in 1896. A 3-ft. vein in granodiorite strikes northeast and dips 75° northwest. Ore shoot 150 ft. long and as much as 6 ft. wide contains appreciable amounts

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Eagle (continued)						of pyrite, galena, and sphalerite. Developed by 780-ft. drift adit and 240-ft. shaft. (Irelan 88:178; Crawford 96:139; Tucker 19:285.)
	Eagle						See Ohio.
81	Eagle King	Marian S. Clark, c/o Eagle King Mining Company, 209 Edgewater, Balboa	4,9	9N	13E	MD	Two miles north of Grizzly Flat. Active 1894-96. A north to northeast-striking vein with 75° west to vertical dip is on or near granodiorite-mica schist contact. Vein is three to four feet wide and contains appreciable amounts of pyrite, galena, and sphalerite. Developed by 1200-ft. drift adit and 60-ft. winze 200 ft. from portal. Ore was treated in 10-stamp mill. (Irelan 88:178; Crawford 94:108-109; 96:139; Tucker 19:285.)
	East Lode						See Beebe.
	Edmunds						See No. 2.
	Edner	D. K. Moore, Omo Ranch	8	8N	13E	MD	One and one-half miles southeast of Omo Ranch. Active in 1896. A $1\frac{1}{2}$-ft. vein in granodiorite strikes north and dips 65° west. Developed by 150-ft. adit and 50-ft. shaft. (Crawford 94:109; 96:139-140; Tucker 19:285.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	El Dorado Big Tunnel Company			11N	11E	MD	During the 1890's this concern operated a mine at Big Canyon two miles north of Placerville which later was purchased by the Gentle Annie Mining Company. (See also Gentle Annie and River Hill Group.)
	El Dorado Crystal						See Crystal.
	Elliott (Sir Walter Raleigh)	Not determined	19	10N	11E	MD	On Mother Lode two miles south of Placerville. Active around 1894. A 4-ft. vein in slate strikes northwest and dips 80° northeast. Developed by 50-ft. inclined shaft and crosscut adit. (Crawford 94:109; 94:140.)
	Emma	Mabel H. Poheim, 598 Bush Street, San Francisco	21,28	12N	10E	MD	Two miles northwest of Garden Valley on Mother Lode. Active prior to 1890. Developed by 100-ft. shaft. (DeGroot 90:176; Crawford 96:140.)
	Empire Group						See Polar Bear.
82	Epley Consolidated (Mammoth)		20	10N	11E	MD	Also see Placerville Gold Mining Company. (Irelan 88:186-187; DeGroot 90:173; Crawford 96:109.)
	Equator	Not determined		10N	11E	MD	Three miles south of Diamond Springs on Mother Lode. Active 1888-90. Three veins in slate strike northeast and dip southeast. Developed by 1300-ft. crosscut adit and 110-ft. inclined shaft. (Irelan 88:190; DeGroot 90:172; Crawford 94:109.)
	Esperanza						See Skipper.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Esperanza (Garden Valley)	Not determined	28	12N	10E	MD	One mile northwest of Garden Valley. Active 1890-1900. A northwest-trending vein associated with lens of amphibolite in slate developed by 600-ft. vertical shaft and 700 feet of drifts. Ore treated in 20-stamp mill. (DeGroot 90:175; Crawford 94:109; 96:140; Tucker 19:285; Logan 34:23-24.)
	Eureka		11	12N	10E	MD	See Woodside-Eureka and Beebe.
	Eureka	L. A. Frontz, Georgetown	2,11	12N	10E	MD	In Georgetown. Active prior to 1888. Three parallel veins in Mariposa slate strike northeast and dip 60° southeast. Veins are 6-10 ft. wide. Developed by 240-ft. inclined shaft and 500 feet of drifts. See also Beebe. (Irelan 88:182; DeGroot 90:178; Preston 92:203; Crawford 94:109; Tucker 19:285.)
	Eureka		6 36	10N 11N	11E 11E	MD MD	See Placerville Gold Mining Company. (DeGroot 90:178; Preston 92:203; Crawford 94:109; Tucker 19:285.)
	Excelsior Consolidated						See Garfield and Excelsior Consolidated.
83	Expansion	Life Estate of Josie G. Pine, c/o John Charles Pine et al., Route 2, Box 34, Placerville	17	10N	10E	MD	Three miles north of Shingle Springs. Active 1900-04; prospected in 1936. Disseminated auriferous pyrite in amphibolite schist. Developed by 150-ft. crosscut adit. (Logan 38:229.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
84	Falls	Mary A. Simpson et al., Box 212, El Dorado	1	9N	10E	MD	On Mother Lode two miles south of Diamond Springs. Active in 1914 and again around 1934. Vein in Mariposa slate. Developed by 235-ft. crosscut adit. (Tucker 19:285; Logan 34:24.)
	Faraday		20,17, 18	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:186; DeGroot 90:173; Crawford 94:110.)
	Flagstaff	Not determined					A few miles north of Grizzly Flats. Active around 1888. Ore treated in 10-stamp mill. (Irelan 88:110; Crawford 96:178.)
	Fort Yuma	Capital Company, 1 Powell Street, San Francisco 2	29, 32	9N	10E	MD	On Big Canyon Creek two miles northeast of Brandon Corner Active 1890-1902 and again in 1938. A 2- to 4-ft. vein in Calaveras slate strikes north and dips east. Developed by 175 and 40-ft. shaft and drifts. Ore treated by flotation . (Crawford 94:110; 96:140; Logan 38:229.)
85	French Creek	William Lange and L.W. Loomis, Placerville	31	9N	10E	MD	Herein.
86	Frog Pond and Marigold Consolidated (Marigold Consolidated)	Not determined	28	12N	10E	MD	One-half mile northwest of Garden Valley. Active intermittently 1914-27. Flat gold-bearing seams with arsenopyrite in amphibolite. Developed by 60-ft. shaft, drift. Ore was treated in 2-stamp mill. (Tucker 19:286; Logan 38:230.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
87	Funny Bug (Pendelco)	R. V. Montgomery, Route 2, Box 193-K, Placerville	5	10N	10E	MD	(Logan 38:242-243; Eric 48:230; herein.)
	Gamblin						See Gambling.
88	Gambling (Gamblin)	Jean E. Carlson, 211 Palomares Drive, Ventura	5	8N	12E	MD	Two miles southwest of Fairplay. Active 1915-18 and 1933-34. An 18- to 30-inch vein in granodiorite strikes west and dips 80° south. Developed by 500-ft. inclined shaft, considerable drifting, and adit on 90-ft. level. Ore was treated in 45-ton mill with 10 stamps, plates, and Frue vanners. (Logan 35:23; 38:230-231.)
	Garden Valley						See Esperanza.
	Gardner Consolidated	W. H. Myers, 24 Bedford Avenue, Placerville	6	10N	11E	MD	One mile north of Placerville. Active prior to 1914. A 5-ft. vein in Mariposa slate strikes north 40° east and dips 70° east. Developed by 400-ft. crosscut adit and 500 ft. of drifts. (Tucker 19:286.)
	Garfield	Not determined	18 or 19	13N	11E	MD	One mile south of Volcanoville. Active around 1894. Vein in slate strikes north and dips 55° west. Developed by 120-ft. inclined shaft and 700-ft. crosscut adit. (Crawford 94:110; 96:141; Tucker 19:286.)
89	Garfield and Excelsior Consolidated	Not determined	5,6	12N	10E	MD	One mile northeast of Greenwood. Active around 1894. A 20-ft. vein in slate with mineralized footwall. Developed by four crosscut adits, 200 to 400 ft. long. (Crawford 94:111; 96:141; Tucker 19:286.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Garibaldi Consolidated	Not determined					Near Greenwood. Prospected around 1894. A 6-ft. vein in slate strikes northwest and dips northeast. (Crawford 94:111.)
	Gentle Annie		6	10N	11E	MD	See River Hill. (De Groot 90:177; Crawford 94:111; 96:141-143; Storms 00:94; Logan 34:45.)
	Georgia Slide						See Seam gold section.
90	German (Haeger)	Hazel A. Hill, Box 12, El Dorado	14	9N	10E	MD	On Mother Lode three miles south of El Dorado. Active around 1896-1900. Vein in Mariposa slate strikes north and dips 60° east. Developed by 500-ft. inclined shaft. Ore was treated in 10-stamp mill. (Crawford 96:142; Storms 00:90; Tucker 19:286.)
	Gloriana	Not determined	29	9N	13E	MD	At Henry's Diggings two miles north of Omo Ranch. Long idle.
	Gold Coin						See Veerkamp.
	Golden Gate						See McNulty.
	Golden Oak						See Big Four.
	Golden Queen						See Chaparral.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Golden Trace (Bullard)	Not determined		9N	13E	MD	Two and one-half miles north of Grizzly Flat by North Fork Cosumnes River. Active prior to 1896. A $2\frac{1}{2}$-ft. vein in granite trends north and dips west. Developed by 250-ft. drift adit. (Crawford 96:143.)
	Golden Unit						See Argonaut.
	Gold Hill						See Brust.
	Gold Note	Not determined	4	8N	13E	MD	Two miles southeast of Omo Ranch. Long Idle.
	Gold Note						See Philadelphia and Gold Note.
	Gold Queen						See Crown Point Consolidated.
	Gold Reserve						See Pyramid.
	Gold Star						See Coe Hill.
	Good Luck	Not determined		10N	11E	MD	Two miles east of Diamond Springs. Active 1909-10. An 18-inch vein in Mariposa slate strikes north 20° east and dips 45° east. Developed by 250-ft. shaft and 200- and 300-ft. adits. Ore treated in 5-stamp mill. (Tucker 19:287.)
	Good Luck						See Jones.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
91	Gopher-Boulder	W. A. Bell, Box 100, Garden Valley	11,14	11N	10E	MD	On Mother Lode one mile northwest of Kelsey. Active 1858 when $15,600 produced; $40,000 produced in 1880's; prospected in 1931 and again during 1934-36. Two veins in slate and greenstone up to 50 ft. in width; Gopher vein strikes north 23° west; Boulder vein strikes north 11° west; both dip northeast. Ore averaged $2.50 to $6 per ton; a few areas contained as much as $16 per ton. Developed by 260-ft. inclined shaft with levels at 50-ft. intervals, a 200-ft. drift adit, 850-ft. crosscut adit, and open cuts. Ore was treated in 20-stamp mill and two Huntington mills. (Irelan 88:175-177; Crawford 96:143; Storms 00:98; Tucker 19:287; Logan 34:24-25.)
92	Grand Victory	Provident Minerals Corporation, c/o Floyd Singleton, 459 Turk Street, San Francisco 2	33,34	10N	11E	MD	(Irelan 88:194; DeGroot 90:178; Crawford 94:112; 96:143; Tucker 19:287; Logan 35:23; 38:231-232; herein.)
	Gray (Old Gray)	Not determined		10N	9E	MD	Three miles northwest of Shingle Springs. Active about 1894. A 1- to 3-ft. vein strikes west, dips 45° north, and is near gabbro body. Developed by 100-ft. shaft and drift. (Crawford 94:119; 96:143.)
	Green	Not determined	19	13N	11E	MD	A chromite mine originally mined for gold. See in Chromite section.
	Greenstone						See Barnes-Eureka

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
93	Greenwood	Not determined	12,13	12N	9E	MD	At Greenwood. Intermittently active 1937-40. Gold occurs in seams across width of 200-ft. open pit. Ore treated in mill with ball mills and cyanidation. (Logan 38:232.
94	Griffith Consolidated	Frank B. Richards et al., Box 611, Placerville	30,31	10N	11E	MD	On Mother Lode one-half mile southeast of Diamond Springs. Worked originally in 1850's, active 1888-90, 1896, and 1903. A 5- to 12-ft. vein in slate strikes northeast and dips southeast. Ore yielded from $4.25 to $8 per ton, although in a few areas it yielded as much as $65 per ton. Developed by 700-, 150-, and 253-ft. shafts and drifts. Ore was treated in 5-stamp mill. (Irelan 88:189; DeGroot 90:172; Crawford 94:112; 96:144; Storms 00:92-93; Tucker 19:287; Logan 34:25-26.)
95	Grit (Liddicoat, Spanish Dry Diggings)	Liddicoat Gold Mines Company, Inc., c/o Joseph L. Liddicoat, Route A, Box 27, Greenwood	30	13N	10E	MD	(Logan 20:426; 23a:29; 23b:44; 24:8; 26:414; 34:44,46; herein.)
96	Gross Consolidated		6	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:181-182; DeGroot 90:173; Crawford 94:113; 96:161.)
	Grouse Gulch	Not determined	16	9N	13E	MD	One and one-half miles west of Grizzly Flat. Active prior to 1888. A vein in granitic rock strikes north and dips 60° west, and ranges from $\frac{1}{2}$ ft. to 5 ft. in width. Developemnt by 100-, 80-, and 50-ft. shafts, drifts and 200-ft. drain tunnel. (Irelan 88:178;

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Grouse Gulch (continued)						Crawford 94:113; 96:144; Tucker 19:288.)
97	Guildford (Poverty Point)	A. A. McKinnon, Placerville	25,36 6	11N 10N	10E 11E	MD MD	On Mother Lode two miles north of Placerville. Active 1912-17, when more than $200,000 produced; intermittently active 1920-25; minor production 1931-32. Two parallel veins in Mariposa slate strike north 20° west and dip 70° southeast. Two ore shoots, 200 and 400 ft. long averaging 5 ft. in width, were mined. Ore yielded $4 to $5 per ton while pyrite concentrate ranged from $40 to $88 per ton. Developed by four drift adits, 500, 600, 700, and 1500 ft. long. Ore treated in 15-stamp mill with Wilfley tables and Frue vanners. (Tucker 19:287-288; Logan 26:414; Knopf 29:49; Logan 34:36-37.)
	Haeger						See German.
	Hall Consolidated						See River Hill group.
	Halleck						See Placerville Gold Mining Company.
	Hardscratch	Not determined		9N	13E	MD	Two miles west of Grizzly Flat. Active around 1896. A northeast trending vein in granite dips northwest. Developed by 120-ft. crosscut adit, 100-ft. drift, and 26-ft. shaft. Ore treated in small Dyer mill. (Crawford 96:144.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
98	Harman group		6,7, 36	10N 11N	11E 10E	MD MD	See Placerville Gold Mining Company. (Irelan 88:181-182; DeGroot 90:173,178; Preston 92:203; Crawford 94:109, 113; 96:161; Tucker 19:285; Logan 34:26.)
	Havilah						See Nashville.
99	Hazel Creek	Fay M. R. Gunby, Box 752, Placerville Leased by Hazel Creek Mining Company, P.O. Box 508, North Sacramento	3	10N	13E	MD	(Herein.)
100	Henrietta		20	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:186; DeGroot 90:173; Crawford 94:113.)
	Hidden Treasure	Not determined	8	8N	13E	MD	One mile northeast of Indian Diggins. Long idle.
	Hillside Group						See Martinez.
101	Hines-Gilbert	Wayne Huckaby, 201 South 8th Street, Sacramento	23,24	13N	9E	MD	On north end Mother Lode one mile northwest of Spanish Dry Diggings by American River. Active 1921-28, 1934; prospected in 1954. Two northwest-striking quartz veinlets occur in slate and amphibolite schist. Developed by open cut 150 ft. in width and 450-ft. adit.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Hines-Gilbert (continued)						Ore treated in 10-stamp mill. (Logan 21:427; 23a:209; 24:178-179; 26:414; 34:27-28, 46.)
	Holly	Not determined	7	10N	11E	MD	In Placerville. Active in 1918.
	Homestead	Not determined	26	13N	10E	MD	Two and one-half miles north of Georgetown. Active 1912-13.
	Hope		16	9N	13E	MD	South extension of Mount Pleasant mine. (Crawford 94:113.)
	Humbug						See Morey.
	Humphrey	Not determined		8N	12E	MD	Two and one-half miles southwest of Fairplay. Active around 1896. A 16- to 24-inch vein in granite strikes west and dips 80° south. Contains pyrite and galena. Developed by 15-ft. shaft and 70-ft. drift. (Crawford 96:145.)
	Hustler						See Adjuster.
	Ibid		21	9N	13E	MD	See also California Consolidated. (Crawford 94:113; 96:145.)
	Ida		18	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:182-183.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Idaho	Hazel A. Hill, Box 12, El Dorado	14,23	9N	10E	MD	Three miles south of El Dorado; long idle. (Tucker 19:288.)
102	Ida Livingston	Ida Livingston Gold Mining Company, 413 High Street Klamath Falls, Oregon	13	11N	10E	MD	On Mother Lode one mile north of Kelsey. Active prior to 1914. A 25-ft. vein in Mariposa slate strikes north 50° east and dips 80° southeast. Ore yielded up to $26 per ton. Developed by 150-ft. shaft. (Tucker 19:288; Logan 34:28.)
	Idlewild						See Taylor.
	Independence	Starlight Mining Co., 2626 Baker Street San Francisco	10	9N	10E	MD	A pocket mine two miles southwest of El Dorado. Active prior to 1914. (Tucker 19:288.)
	Independence	Not determined	27	12N	11E	MD	Four miles northwest of Slate Mountain. Active in 1933; ore treated in 2-stamp mill.
103	Inez (Central	M. B. Maginess, 1400 Vilvo Street San Francisco	1	8N	10E	MD	One mile east of Nashville. Active around 1890. Vein in slate strikes northwest and dips 60° northeast. Developed by 250-ft. shaft. (DeGroot 90:171; Crawford 94:114; 96:147; Tucker 19:288.)
	Iowa						See Beebe.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
104	Isabel (Isbell)	Helen B. King, 20 Molly Lane, Placerville	3	11N	10E	MD	On Mother Lode one mile southeast of Garden Valley. Active prior to 1914. A 2- to 8-ft. vein in slate strikes northwest. Developed by open cuts and 30-ft. shaft. Ore was treated at the Blue Lead Mill. (Tucker 19:288-289; Logan 34:28.)
	Isbell						See Isabel.
	Ivanhoe	Not determined	28	12N	10E	MD	One-half mile northwest of Garden Valley. Active prior to 1890. A vein in slate and greenstone strikes northwest and dips northeast. Developed by open cuts and 200-ft. shaft. (DeGroot 90:175-176; Crawford 94:114; Tucker 19:289.)
	James Marshall						See Big Sandy.
	Jones (Good Luck)	Not determined	6	9N	11E	MD	Two miles south of Diamond Springs. Active in 1915 and during 1922-23 when several thousand dollars produced. Vein strikes west. Developed by shaft with levels at 75, 165, and 225 feet and drifts. (Logan 23a:45; 23b:142.)
105	Josephine	J. A. Shields and Lester Marks, Auburn	5,6, 7,8	13N	11E	MD	At Volcanoville. Active 1889-90, 1896, 1920, and 1934-35. A 6-ft. vein with ribbon structures in slate and serpentine strikes northeast and dips 45° southeast. Ore shoots are up to several hundred feet in length. Developed by five drift adits. Ore was treated in 20-stamp mill. (Irelan 88:165-166; DeGroot 90:178;

LODE GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Josephine (continued)						Preston 92:206; Crawford 94:114; 96:147; Tucker 19: 289; Logan 20:427.)
	Kaeser						See Boulder.
	Kelly	Not determined	13	11N	10E	MD	On Mother Lode one-half mile north of Kelsey. Active around 1902 and 1932. A 6-ft. vein in Mariposa slate strikes north. Developed by two 50-ft. shafts. (Logan 34:29.)
	Kelly						See Dalmatia.
106	Kelsey (Lady)	A.P.O. Crabtree, 616 North F Street, Porterville	24,25	11E	10E	MD	(Tucker 19:289; Logan 34:29, 211; 38:235, 236; herein)
	Lady						See Kelsey.
	Lady Blanche	Not determined	36	9N	12E	MD	Three and one-half miles east of Fairplay. Active in 1896. A 1- to 4-ft. vein strikes north 20° west and dips 50° northeast with slate footwall and porphyry hanging wall. Developed by 180-ft. and 80-ft. adits. (Crawford 96:147; Tucker 19:289.)
107	Lady Emma	J. L. Peters, Kelsey	13	11N	10E	MD	One mile east of Kelsey. Active around 1896; prospected in 1942 and 1947. A 4-ft. vein in slate and porphyry strikes north and dips 60° east. Developed by 300-ft. inclined and 150-ft. vertical shafts with drifts and

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Lady Emma (continued)						crosscuts. Ore was treated in 10-stamp mill. (Crawford 96:147-148; Tucker 19:289.)
108	La Moille	Walter Bidstrup, Box 35, El Dorado	11	9N	10E	MD	Three miles south of El Dorado. Active prior to 1894. A number of quartz seams trend north. (Crawford 94: 115; 96:148.)
109	Larkin (Diamond Springs)	Bernard B. Ball, 122 Bedford Avenue Placerville	29	10N	11E	MD	(Crawford 96:148; Storms 00:93; Lang 07:963; Aubury 08:217; Tucker 19:277,289; Logan 26:407-408; 34:30; 47:233; Eric 48:231; herein.)
	Last Chance	Not determined	19	13N	11E	MD	One mile south of Volcanoville. Active in 1896. A 5-ft. vein in slate and porphyry strikes west and dips 55° south. Developed by 50-ft. vertical shaft and 400-ft. crosscut adit. Ore treated in 4-stamp mill. (Crawford 96:148.)
	Last Chance						See Briarcliffe.
	Liddicoat						See Grit.
	Live Oak	Frank Richards et al., Box 611, Placerville	30	10N	11E	MD	One mile east of Diamond Springs. Active prior to 1896; a vein in slate and greenstone strikes north and dips east. Developed by 30-ft. shaft. (Crawford 96:149.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
110	Log Cabin (Darrow)	T. E. Massie, c/o John Kessler, 550 Swanston Drive, Sacramento	30	9N	10E	MD	Five miles south of Shingle Springs. Active 1894-96. A 2- to 16-ft. vein in slate and serpentine strikes northwest and dips 65° northeast. Developed by 600-ft. crosscut adit, drifts, and 30-ft. shaft. Ore was treated in 5-stamp mill. (Crawford 94:116; 96:149; Tucker 19:289.)
111	Lone Jack	John W. Reiss et al., Garden Valley	28	12N	10E	MD	On Mother Lode one mile northwest of Garden Valley. Active 1890-96. A vein up to 24 ft. in width contained $6 per ton. Developed by 400-ft. shaft. Ore was treated in 10-stamp mill. (DeGroot 90:176; Crawford 94:116; 96:149; Tucker 19:290.)
112	Lone Star	Camilla D. Heald, 624 South 13th Street San Jose	11	8N	10E	MD	One mile southeast of Nashville between the forks of the Cosumnes River. Active around 1894. A 7-ft. vein in slate strikes north and dips 60° east. Developed by 100-ft. shaft and 100-ft. drift. Ore was treated in two 5-ft. Huntington mills. (DeGroot 90:178; Crawford 94:116; 96:149; Tucker 19:290.)
113	Lone Star	Frank B. Richards et al., Box 611, Placerville	31	10N	11E	MD	Two miles southeast of Diamond Springs. Active 1894-96 and 1907-08. A 2- to 5-ft. vein in slate and greenstone strikes northeast with vertical dip. Developed by 500-ft. crosscut adit. (Crawford 94:116; 96:149; Tucker 19:290.)
114	Lookout	Hazel A. Hill, Box 12, El Dorado	11	9N	10E	MD	On Mother Lode three miles southwest of El Dorado. Intermittently active from 1860 to 1930's; $2,200 produced in 1912, $15,000 in 1933. Gold is in small but rich ore shoots in vein in Mariposa slate. Developed

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	Lookout (continued)						by 400-ft. adit. (Tucker 19:290; Logan 22:45; 34:30.)
	Lookout and K. K.	Not determined	19	13N	11E	MD	In Quartz Canyon near Volcanoville. Active 1894-96. A 2-ft. vein in slate and porphyry strikes north and dips east. Developed by 200-ft. crosscut adit, drifts, and 34-ft. inclined shaft. (Crawford 94:116; 96:149; Tucker 19:290.)
115	Loveless	Hazel Hill, Box 12, El Dorado	11,14	9N	10E	MD	Three miles south of El Dorado. Active around 1914. A 1-ft. vein in slate and diabase strikes north and dips 47° west. Ore occurs in pockets. Developed by 160-ft. crosscut adit, 300-ft. drift, and 90-ft. shaft. (Tucker 19:290.)
	Lucinda	Not determined		9N	13E	MD	Three miles west of Grizzly Flat. Active prior to 1896. A 6-in. to 3-ft. vein in granodiorite and slate strikes west and dips 70° north. Developed by 50-ft. vertical shaft and 150-ft. crosscut adit. (Crawford 96:149; Tucker 19:290.)
	Lucky Jack	Walter Bidstrup, Box 35, El Dorado	11	9N	10E	MD	Two miles south of El Dorado. Active around 1914. Series of north-striking veins in granodiorite. Developed by several shallow shafts. Ore was treated in 2-stamp mill. (Tucker 19:290.)
	Lucky Marion (Shepard)	Not determined	12	12N	9E	MD	On Mother Lode one-half mile west of Greenwood. Active 1896-97 and again in 1901 when $3,860 produced. An 18- to 24-inch vein strikes north 30° west and dips 56° northeast with serpentine hanging wall and slate footwall. Developed by 112-ft. inclined shaft. Ore treated in 20-stamp mill. (Crawford 96:150; Tucker 19:290; Logan 34:30.)
	Lucky Star						See River Hill.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
116	Lukens	P.E. Bottorf, Route 4, Box 6, Placerville	25	12N	8E	MD	Three miles southwest of Cool. Active around 1923. A narrow vein in amphibolite yielded some high-grade ore. Developed by 60- and 90-ft. shafts connected by 150-ft. drift. (Logan 23b:142-143; 26:414-415.)
	Lyon						See River Hill.
	Madrona	Not determined	29	12N	10E	MD	Two miles northwest of Garden Valley. Active prior to 1894. Vein in slate contains high percentage of sulfides. Developed by 40-ft. shaft. (Crawford 94:117.)
	Maltby	Not determined	17	12N	10E	MD	On Mother Lode one and one-half miles southeast of Greenwood and just north of Argonaut mine. Prospected during 1930's. Developed by adit.
117	Mammoth	Dorothy F. Kipp, Coloma	3,4	10N	9E	MD	One mile northwest of Deer Valley School. Opened in 1860 when $10,000 produced from pocket; dump worked in 1934. A 3- to 4-ft. vein in granodiorite strikes northeast and dips northwest while 5-ft. vein strikes west. Developed by 75-ft. crosscut adit and 120-ft. drift; ore treated in 10-stamp mill. (Crawford 96:150; Tucker 19:290; Logan 38:237.)
	Mammoth						See Epley Consolidated and Placerville Gold Mining Company.
	Manhatten-California						See Manhatten Consolidated.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
118	Manhatten Consolidated (Manhatten-California)	T. N. Reiman, 1616 S. Tuxedo Avenue, Stockton	36	9N	10E	MD	Two miles northeast of Nashville. Active prior to 1915; prospected in 1935, 1947, and 1952. Developed by 400-ft. shaft. (Tucker 19:291.)
	Manzanita	Not determined	24	11N	10E	MD	On Mother Lode one mile south of Kelsey. Active in 1918.
	Manzanita Queen						Extension of Griffith Consolidated. (Irelan 88:189.)
119	Marguerite	Loren, Ralph, and Berthal Crain, and Wilma Berriman, Plymouth	20,29	10N	11E	MD	One mile east of Diamond Springs. Active prior to 1914. Three parallel veins in Mariposa slate strike north and dip 70° east. Developed by 300-ft. vertical shaft, 200-ft. adit, and 1200 ft. of drifts. (Tucker 19:291.)
	Marigold Consolidated						See Frog Pond and Marigold Consolidated.
120	Martinez (Hillside group)	Martinez Gold Mines Company, Post Office Box 61, El Dorado	12,13	9N	10E	MD	(Tucker 19:288; Logan 26:415; 34:30-31; 38:237-238; herein.)
	Maryland						See Placerville Gold Mining Company.
	Mathenas Creek (Schneider)	Sophia (Schainman) Haut, 740 - 35th Avenue, San Francisco 21	31	10N	11E	MD	One mile south of Diamond Springs. Active 1888-94. A 2- to 8-ft. vein in slate strikes north 20° west and dips 55° northeast. Developed by 100- and 300-ft. adits. Ore treated in Huntington mill.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Mathenas Creek (continued)						(Irelan 88:190; DeGroot 90:172; Crawford 94:117; 96:150; Tucker 19:291.)
121	McNulty (Golden Gate, Oakland)	Hazel A. Hill, Box 12, El Dorado	14,23	9N	10E	MD	Three miles south of El Dorado on Mother Lode. Active 1890-94. A 6-ft. vein strikes north and dips 60° east with slate hanging wall and greenstone footwall. Developed by 400-ft. shaft, 450-ft. crosscut adit, and 450-ft. winze sunk from adit. Ore was treated in 10-stamp mill. (DeGroot 90:171; Crawford 94:117; 96:150; Tucker 19:296.)
	Melton						See **Cosumnes.** (Irelan 88:178-180; Crawford 94:117; 96:150; Tucker 19:291; Logan 38:238.)
	Middle End						See **Cosumnes.** (Logan 26:418.)
	Miller (Ribbon Rock)	Not determined		10N	11E	MD	On Mother Lode two miles south of Placerville. Active 1888-94, 1900. A 2- to 5-ft. vein in slate strikes north 12° west and dips 65° northeast. Much ribbon structure. Developed by 400-ft. inclined shaft. (Irelan 88:189; DeGroot 90:172; Crawford 94:122; 96:150; Storms 00:94; Tucker 19:291; Logan 34:31.)
	Mitchell	Not determined	7	10N	9E	MD	Two miles northwest of Pine Hill. A 4- to 10-ft. vein developed by 150-ft. adit. (Logan 38:238.)
122	Monarch-Sugar Loaf	Leased by George Ross, Placerville	27	9N	10E	MD	Herein.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Montana	Not determined	19	13N	11E	MD	One mile south of Volcanoville. Active 1896. A 14-ft. vein in slate and porphyry strikes north and dips 50° east. Developed by 45-ft. inclined shaft and crosscut adit. Ore treated in 1-stamp mill. (Crawford 96:151; Tucker 19:291.)
	Montauk Consolidated						See Zantgraf.
123	Montezuma-Apex and Montezuma Extension	Montezuma-Apex Mining Company., c/o of National Tunnel and Mines Company, 818 Kearns Building Salt Lake City, Utah	35 2	9N 8N	10E 10E	MD MD	(Crawford 94:118; 96:151; Storms 00:91: Tucker 18: 291; Logan 26:415-416; Huttl 35a:173-175; Logan 38:238-240; herein.)
	Montezuma Extension						See Montezuma-Apex.
124	Morey (Humbug)	E. W. Morey, Grizzly Flat	16	9N	13E	MD	One mile west of Grizzly Flat. Active intermittently from 1919-44. Small amounts of high-grade ore occur in small veins. Developed by numerous shallow shafts. Ore was treated in small mill on property. (Logan 38: 241; Heyl and others 48:230.)
125	Morman Hill	Joseph J. Kaline, 2131 Lake Street, San Francisco 21	5	10N	9E	MD	Four miles northwest of Rescue. Active 1934, 1938-41. A 24- to 30-inch vein strikes north 40° east and dips northwest. Developed by 110-ft. inclined shaft with 80 ft. of drifts on 100-ft. level. Ore treated in 5-stamp mill. (Logan 38:241.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Morse	Not determined					Three miles east of Latrobe on west side of large serpentine body. Active prior to 1894. (Crawford 94:118.)
126	Mount Hope	H. E. West, Box 752, Placerville	34	10N	13E	MD	Three miles north of Grizzly Flat. Active prior to 1888. A vein in granodiorite is developed by 1000-ft. adit, 200- and 100-ft. shafts. Ore treated in 10-stamp mill. (Irelan 88:178; Crawford 96:151; Tucker 19:292.)
127	Mount Pleasant	Annie S. Kirk, Box 507, Placerville	16	9N	13E	MD	(Irelan 88:178; DeGroot 90:178; Crawford 94:118; 96:151; Tucker 19:292; Logan 22:209,301; 26:416-417; 38:241-242; herein.)
128	Nashville (Havilah, Tennessee-Nashville)	Montezuma-Apex Mining Company, c/o National Tunnel and Mines Company, 818 Kearns Building, Salt Lake City, Utah	2	8N	10E	MD	(Crawford 94:119; 96:151; Storms 00:91; Tucker 19:292-293; Hamilton 22:30; Logan 22:45,209; 34:27; herein.)
	National						See Briarcliffe.
	New Deal						See U. S. Grant.
	New Eldorado	H. V. Colby, 210 Stone Wall Road, Berkeley 5	25	13N	9E	MD	Twc and one-half miles north of Greenwood. Active around 1894. Vein containing specimen gold strikes north and dips east; developed by adit.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	New Eldorado (continued)						(Crawford 94:119; 96:152; Tucker 19:293.)
	New Era						See River Hill.
	No. 2 (Edmunds)	Not determined		10N	9E	MD	One mile northwest of Rescue. Active 1938, when 100 tons ore was mined. A 2-ft. vein contains high-grade gold pockets. (Logan 38:242.)
	North St. Lawrence						See St. Lawrence.
129	Oak	Arthur S. Morey et al., 91 Rico Way, San Francisco 23	32	9N	13E	MD	One mile northeast of Omo Ranch. Active 1894. A 1- to 4-ft. vein in granite containing much sulfide strikes northeast and dips 75° northwest. Developed by 400-ft. and 150-ft. drift adits. Ore treated in 5-stamp mill. (Crawford 94:119; 96:152; Tucker 19:293.)
	Oakland						See McNulty.
130	Ohio (Eagle)	Not determined	7	12N	10E	MD	One mile east of Greenwood. Active in 1894-96. A 4-ft. vein with stringers in slate strikes northwest and dips 51° northeast. Developed by 250-ft. inclined shaft. (Crawford 94:119; 96:152,157; Tucker 19:293.)
131	Ohio	Albert N. Brown et al., 5252 James Avenue, Oakland	16,21	9N	13E	MD	One mile southwest of Grizzly Flat. Active prior to 1894. A 4-ft. vein contained ore shoot several hundred ft. long. Ore averaged $12 per ton. Developed by 135-

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Ohio (continued)						ft. vertical shaft and and an inclined shaft. (Crawford 94:119; 96:152.)
	Old Gray						See Gray.
	Old Harmon						See Placerville Gold Mining Company.
	Old Jasper	Not determined		10N	9E	MD	Nine miles northwest of Shingle Springs. Active prior to 1896. Two parallel veins 3 and 4 ft. wide in granodiorite strike north. Developed by 200-ft. drift adit and inclined shaft. (Crawford 96:152.)
132	Omo	Not determined	32	9N	13E	MD	One mile northeast of Omo Ranch. Active 1896. A $1\frac{1}{2}$-to 3-ft. vein in granodiorite strikes north, dips west near surface, but dips east in depth. Sulfides run one percent. Developed by 150-ft. adit and 64-ft. shaft. Ore treated in 125-ft. flume with pole riffles. (Crawford 96:152-153; Tucker 19:293.)
	One to Sixteen and Vulture	Not determined	6,7	10N	11E	MD	One mile north of Placerville. Long idle. (Tucker 19:293.)
133	Ophir	C. A. Clark, P.O. Box 41, El Dorado	11	9N	10E	MD	On Mother Lode two miles south of El Dorado. Active 1932-34; prospected 1951-52. A 14-inch vein and stringers in a brecciated zone in quartz porphyry and greenstone contain pyrite and arsenopyrite. Some high-grade ore produced. Developed by adit and shaft; ore treated in 2-stamp mill. (Logan 34:34-35.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
134	Oregon		18	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:182-183; DeGroot 90:173; Crawford 94:119; 96:153.)
	Oregon Extension						See Placerville Gold Mining Company.
	Oregon Hill						See Placerville Gold Mining Company.
	Oriflamme						See Oro Flam.
	Oro Fino						See Big Canyon.
	Oro Fino	Not determined	33	12N	10E	MD	On Mother Lode one mile south of Garden Valley. Active 1925-26, 1930. A 4-ft. vein in amphibolite strikes northwest and dips 50° northeast. Some high-grade produced. Developed by 80-ft. inclined shaft. Ore treated at Frog Pond mill. (Logan 26:417; 34:35.)
	Oro Flam (Oriflamme)	Mill B. Maginess, et al., 1400 Ulloa Street, San Francisco	31	10N	11E	MD	On Mother Lode one mile southeast of Diamond Springs. Active 1888-90. A vein 1 to 10 ft. wide lies between slate and diorite. Developed by 350-ft. adit and 40-ft. shaft. (Irelan 88:189-190; DeGroot 90:173; Tucker 19:293.)
	Oronogo	Ruth Frazier, Garden Valley	34	12N	10E	MD	One mile south of Garden Valley on Mother Lode. Active 1953-55 with small gold output. Two parallel veins in slate with much gouge strike north and dip east. Developed by 90-ft. inclined shaft with 20-ft. drift south on 90-ft. level.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Orum (Woodland)	Cecilia Simpson, 4029 Kuhnle Street, Oakland	12	9N	10E	MD	On Mother Lode three miles east of El Dorado. Active 1914. A 1-ft. vein in Mariposa slate strikes north and dips 80° east; free-milling ore with two percent pyrite. Developed by 200-ft. vertical shaft with levels at 100 and 150 ft. Ore treated in 5-stamp mill with Wilfley table (Tucker 19:300; Logan 34:35.)
135	Pacific Quartz	Placerville Gold Mining Company, Box 191, Placerville	17,18 20	10N	11E	MD	See in text under Placerville Gold Mining Company. (Irelan 88:183-186; DeGroot 90:173; Crawford 94:120; 96:163; Tucker 19:293-295; Logan 22:209; 26:417-418; 34:35-36; Bowen and Crippen 48:66,68.)
	Padre	Not determined		9N	10E	MD	On Mother Lode two miles north of Nashville. Active around 1894. A 5-ft. vein developed by 160-ft. shaft. Ore treated in 5-stamp mill. (Crawford 94:120; 96:153.)
	Paymaster	Not determined	20	13N	11E	MD	One mile south of Volcanoville. Active in 1920 and 1926. Ore treated in 10-ton Gibson mill.
	Pendelco						See Funny Bug.
	Philadelphia and Gold Note	George Allen, Sutter Creek	21,22	8N	13E	MD	Three miles southeast of Indian Diggings. Active during 1890's. A 4- to 5-ft. vein in mica schist and slate strikes north 30° west and dips 60° northeast. Ore contains pyrite and galena. An ore shoot 600 ft. in length is worked. Developed by 145- and 125-ft. shafts, and 600-ft. adit. Ore treated in 10-stamp mill. (Crawford 94:120-121; 96:153; Tucker 19:295.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Phillips						See Big Jim.
	Pine Hill (Unity)			10N	9E	MD	Five miles northwest of Shingle Springs. Active during 1890's. A 6-ft. quartz vein in slate and greenstone strikes north contains up to 5 percent sulfides. Developed by 200-ft. shaft, drifts, and crosscuts. (Crawford 94:121; 96:153.)
	Placerville Gold Mining Company	Placerville Gold Mining Company, Box 191, Placerville	6,7 17,18, 20,36	10N 11N	11E 10E	MD MD	Operations include: True Consolidated mine with the Young Harmon, Old Harmon, Halleck and Berry claims; the Van Hooker, Grass, Brown Bear, Cinnamon Bear, White Bear, and Eureka claims; Epley Consolidated mine, composed of the Epley, Faraday, Henrietta and Mammoth claims; and the Rose, Chester, Ida, Oregon and Oregon Extension claims; and Pacific. (Herein.)
	Plattsburg	Not determined	2 or 3	12N	10E	MD	Three-fourths of a mile north of Georgetown. Active in 1896. A 1- to 4-ft. vein strikes north, dips east, and contains coarse gold. Also auriferous channel on property. (Crawford 96:154.)
136	Pleasant Valley	Not determined	13	10N	12E	MD	Four miles northeast of Pleasant Valley. Active 1880's, again in 1935. A $2\frac{1}{2}$- to 6-ft. vein developed by 480-ft. adit and 110-ft. shaft. (Crawford 94:154; Logan 38: 244.)
137	Pocahontas	G. Q. Chase et al., 37 Lincoln Avenue, Piedmont 11	10,11 14,15	9N	10E	MD	On Mother Lode two and one-half miles south of El Dorado. Opened 1854 and intermittently active until 1896; prospected around 1939. Two veins 300 ft. apart strike

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Pocahontas (continued)						northwest and dip northeast, in diorite porphyry. Ore ranged from $4 to $25 per ton in value. Developed by 400- and 300-ft. inclined shafts and about 1700 ft. of drifts. Ore was treated in 10-stamp mill. (Crawford 94:121; 96:154; Storms 00:95; Tucker 19:295; Logan 34:36.)
	Polar Bear (Empire Group White Bear)	Martha Agnes Weber, Placerville and Maryland Casualty Company, 240 Sansome Street, San Francisco	29,32	9N	13E	MD	Three miles south of Grizzly Flat. Long idle. (Tucker 19:295.)
	Poor	F. L. Veerkamp, c/o Stiner's Station, Kelsey	12	11N	10E	MD	One mile northwest of Kelsey. Active around 1938 when 200 to 300 tons ore were mined. Quartz stringers in amphibolite strike north 15 west and dip steeply northeast. Developed by open cuts and 37-ft. shaft. (Logan 38:244.)
	Potosi	Not determined	33	9N	13E	MD	One mile east of Omo Ranch. Active in 1908.
	Potter						See Rising Sun.
	Poverty Point						See Guildford.
138	Pyramid (Gold Reserve)	Rhoads Grimshaw, Auburn	12,13	10N	9E	MD	(Crawford 94:121; 96:154; Tucker 19:295; Logan 35:23; 38:244-246; herein.)
	Rainbow (Wild West)	Not determined	21	12N	10E	MD	One and one-half mile northwest of Garden Valley. Active 1896. A vein system as much as 23 ft. wide strikes north and dips 45° east with porphyry hanging wall and slate footwall. Developed by open cuts and 25-ft. shaft.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Rainbow (continued)						Ore treated in 4-stamp mill. (Crawford 96:155; Tucker 19:295.)
	Rattler	Not determined	20	10N	11E	MD	Two miles south of Placerville by Weber Creek. Active prior to 1894. Developed by two adits. (Crawford 94:122; 96:155.)
	Red Hill	Not determined		12N	10E	MD	Two miles northwest of Garden Valley. Active around 1914. A northwest-striking vein dips northeast and occurs in slate. Developed by 100-ft. inclined shaft and 350-ft. drift. Ore treated in 2-stamp mill. (Tucker 19:295-296.)
	Red Rover	Not determined		9N	10E	MD	Three miles southeast of El Dorado. Active around 1894 and again in 1920. A 6-in. to 3-ft. vein strikes north and dips 60° east with granite hanging wall and slate footwall. Developed by 130- and 30-ft. inclined shafts and 115 ft. of drifts. (Crawford 94:122; 96:155; Logan 20:427-428.)
	Red Top						See Red Wing.
139	Red Wing (Red Top)	David Loofbourrow, 333 California Street, San Francisco	12,13	9N	10E	MD	Three miles south of El Dorado on Mother Lode. Active around 1914-22 and 1926. A 5-ft. vein in Mariposa slate strikes north 10° east and dips 70° southeast. Developed by upper 125-ft. adit and lower 525-ft. cross-cut adit and drifts. Ore treated in a 2-stamp mill. (Tucker 19:296; Logan 23a:301.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Ribbon Rock						See Miller.
140	Richelieu	Mary Ann Simpson, c/o J. P. Conroy, Box 212, El Dorado	12	9N	10E	MD	On Mother Lode three miles south of El Dorado. Active 1932. Small amounts of gold in quartz stringers in slate and gouge. Developed by shaft and 275-ft. adit. Small amount of ore treated at Church mill. (Logan 38:246-247.)
	Richmond	L. G. Fancher, Box 684, Jackson	4 33	8N 9N	13E 13E	MD MD	One mile south of Fairplay. Long idle. Ore treated in 8-stamp mill. (Tucker 19:296.)
	Rising Sun (Potter)	Oviedo Le Bourreau, Box 592, Placerville	14	11N	10E	MD	One mile northwest of Kelsey. Long idle. (Tucker 19:296.)
141	River Hill group (Bell, Gentle Annie, Hall Consolidated, Lucky Star, Lyon, New Era).	A. A. McKinnon, Placerville	6 36	10N 11N	11E 11E	MD MD	A consolidation of claims on Mother Lode one and one-half miles northwest of Placerville. Originally worked about 1865. Active 1890 to 1906; large total output. Five parallel veins in Mariposa slate strike northwest and dip northeast; ore shoots were up to 30 ft. in width and 150 ft. in length; yielded $2.50 to $4.80 per ton in early 1900's. Developed by 600- and 1550-ft. inclined shafts, 2400-ft. adit, and much drifting. Ore treated originally in 10-stamp mill; about 1901, a 20-stamp mill was erected. (DeGroot 90:177; Crawford 94:111; 96:141-142; Storms 00:94; Tucker 19:296; Logan 34:37.)
	Rocky Bar	Not determined		12N	10E	MD	One-half east of Greenwood. Active prior to 1894. A 1-ft. vein in slate strikes northwest. Developed by open cuts and shallow shafts. (Crawford 94:122.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Roscoe	Not determined					Three miles northeast of Latrobe. Prospected in 1896. A 12-ft. vein strikes north and dips west. (Crawford 96:155.)
	Rose		18	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:182-183; Crawford 94:122; 96:155.)
	Rosecrans						See Rosecranz.
142	Rosecranz (Rosecrans)	Arthur S. Morey, 91 Rico Way, San Francisco	21	12N	10E	MD	(Irelan 88:171; DeGroot 90:176; Crawford 96:155; Tucker 19:296; Logan 38:248-249; herein.)
143	Rose Kimberly	Hattie M. Grien, Rescue	10,11	10N	9E	MD	Two miles northwest of Rescue. Active 1895 and again in 1938. Two lensoid veins in gabbro contain pyrite, galena, chalcopyrite; assays range from $1 to $5 per ton. Developed by 220-ft. inclined shaft with levels at 60, 120, and 220 ft. (Logan 38:247-248.)
	Ruby Consolidated	Not determined	17,18 19	13N	11E	MD	One mile south of Volcanoville. Intermittently active 1928-40. Gold associated with serpentine. Developed by 900-ft. adit and 180-ft. vertical shaft. Ore treated in 2-stamp mill. Also a chrome mine; see Chromite tabulated list.
	Ryan	Not determined	24	11N	10E	MD	One mile south of Kelsey. Long idle. (Tucker 19:296.)
	Safeguard No. 1						See Bret Harte.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
144	St. Clair	J. Peters, Kelsey	14	11N	10E	MD	One mile northwest of Kelsey. Active prior to 1915 and again around 1940. (Tucker 19:298.)
145	St. Lawrence	St. Lawrence Gold Mining Company, c/o Wells Fargo, 4 Montgomery Street, San Francisco	3	11N	10E	MD	On Mother Lode one and one-half miles southeast of Garden Valley. Active 1867-78 when $465,000 was produced. A 6-ft. vein in Mariposa slate strikes north 10°west and dips 60° northeast. Ore ranged from $8.54 to $27 per ton in value, but average was $10 to $17. Developed by 900-ft. inclined shaft with levels at 100 ft. and 200-ft. winze sunk from 900-ft. level. Ore treated in 20-stamp mill. (Preston 92:202; Crawford 96:156; Tucker 19:298; Logan 34:40-41.)
	St. Lawrence						See Stillwagon.
	Salisbury	Not determined	33	10N	11E	MD	Three miles southeast of Diamond Springs. Active around 1896. Vein strikes northeast and dips 70° southeast. Developed by 40-ft. inclined shaft. Ore treated in 40-ton mill equipped with two Huntington mills. (Crawford 96:156.)
	Schleifer	Not determined					On east side of Big Canyon seven miles south of Shingle Springs. Active prior to 1894. A low-grade body of auriferous pyrite. (Crawford 94:122.)
	Schneider						See Mathenas Creek.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Selby	Not determined	29	10N	11E	MD	One mile east of Diamond Springs. Active prior to 1900. Developed by 240-ft. shaft. (Storms 00:93; Tucker 19:296.)
	Shan Tsz						See Shaw.
	Sharp	Not determined		10N	11E	MD	Six miles east of Placerville. Opened about 1870; again active in 1890. A 12-ft. vein strikes northwest and dips northeast with granite footwall and slate hanging wall. Developed by 54-ft. shaft and 110- and 108-ft. adits. Ore treated in 10-stamp mill. (Irelan 88:194; Crawford 94;123; 96:156.)
146	Shaw (Shan Tsz, Volo)	Evelyn R. Purser, c/o Richard P. Lyons, 110 Bank Building, South San Francisco Leased by Volo Mining Company, 464 Main Street, Placerville	21	10N	10E	MD	(Irelan 88:193; DeGroot 90:181; Crawford 94:481; Tucker 19:296-297; herein.)
	Shepard						See Lucky Marion.
147	Sherman	Sherman Mining and Milling Company, Placerville	8	10N	11E	MD	On Mother Lode one mile north of Placerville. Active 1905, 1908-11 with production of $136,000. A 5-ft. vein in Mariposa slate strikes north 20° west and dips 74° northeast. Ore was free milling with 3 percent

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Sherman (continued)						pyrite. Ore yielded $3.15 to $6.50 per ton. Developed by 750-ft. inclined shaft with levels at 100, 200, 300, 400, 500, and 750 ft; 350-ft. winze sunk from 750-ft. level; 5500 ft. of drifts. Ore treated in 10-stamp mill with tables and vanners. (Tucker 19:297-298; Logan 34:38.)
148	Shumway	Wilber E. Timm, et al., c/o County Courthouse, Placerville	7	11N	11E	MD	One mile southeast of Spanish Flat. Prospected in 1938. Developed by 100-ft. shaft and 300-ft. crosscut adit. (Logan 38:249.)
	Sir Walter Raleigh						See Elliott.
149	Skipper (Esperanza)	H. R. Swartz, Greenwood	7	12N	10E	MD	(Crawford 96:140; Tucker 19:285; herein.)
	Slate Mountain	E. W. Little, Garden Valley	35	12N	11E	MD	Three miles northwest of Slate Mountain. Active intermittently 1921-41; 1951. A 1½- to 8-ft. vein developed by 600-ft. crosscut adit and 2400 feet of drifts. Ore treated in 10-stamp mill.
150	Sliger	Sliger Gold Mining Company, 3628 Fulton Street, San Francisco	36	13N	9E	MD	(Crawford 94:123; 96:157; Tucker 19:297; Logan 23:157; Tucker 19:297; Logan 23:143; 26:418; 34:38-40; 38:250; herein.)
	South Ohio	Not determined		12N	10E	MD	One and one-half miles east of Greenwood. Active in 1896. An east-striking and north-dipping vein in slate developed by 100-ft. adit. (Crawford 96:157.)
	Spanish Dry Diggings						See Grit.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	Springfield						See Union.
	Standard	John Fitzgerald, 1028 Pendegast Street, Woodland	24	11N	10E	MD	Quarter of a mile north of Coloma. Active around 1894. Seems 2 to 12 in. wide occur near granite-slate contact. Developed by 230-ft. adit. (Crawford 94:123; 96:157.)
151	Starlight	Starlight Mining Co., 2626 Baker Street, San Francisco	3,10	9N	10E	MD	On Logtown Ridge two and one-half miles south of El Dorado. Active 1894-96. A 3-ft. vein strikes northwest and dips 40° northeast. Developed by 500-ft. vertical and two shallow inclined shafts and drifts and cross-cuts. Ore was treated in 10-stamp mill. (Crawford 94:123; 96:157; Tucker 19:298.)
152	Stillwagon (St. Lawrence)	Not determined	32,33	9N	13E	MD	One mile northeast of Omo Ranch. Active 1890-94 and 1908-14. A 2- to 3-ft. vein in granite strikes northeast and dips southeast and is rich in sulfides. Developed by 400- and 200-ft. adits. Ore treated in 5-stamp mill. (DeGroot 90:178; Crawford 94:123-124; Tucker 19:298.)
	Stony Point						See Adams Gulch.
153	Stuckslager	Beryl E. McKenney, 31 Lake Vista Avenue, Daly City 25	24	11N	9E	MD	(Hanks 86:43; DeGroot 90:178; Crawford 94:124; 96:158; Tucker 19:298; herein.)
	Studhorse	Not determined		12N	9E	MD	Two miles west of Greenwood. Active around 1896. An east-striking and north-dipping vein in slate developed by 30- and 40-ft. shafts. (Crawford 96:158.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
154	Sugar Loaf	Sugar Loaf Mining Company, Route 1, Box 57, Shingle Springs	1,12	8N	9E	MD	(Crawford 94:124; 96:158; herein.)
	Sullivan						See Adams Gulch.
	Sunday	Not determined	16	9N	13E	MD	One and one-half miles west of Grizzly Flat. Active around 1894. A 1- to 3-ft. vein in syenite strikes north. Developed by 110-ft. shaft, 80-ft. drift, 300-ft. adit, and open cuts. (Crawford 94:124; 96:158; Tucker 19:298.)
155	Sunrise	John Fitzgerald, 1028 Pendegast Street, Woodland	24	11N	10E	MD	On Mother Lode one mile southeast of Kelsey. Active around 1896. Three parallel veins 9, 15, and 30 ft. thick in slate with associated talc and calcite strike north and dip east. Developed by 320-ft. crosscut adit and several shallow shafts, ore treated in 10-stamp mill. (Crawford 96:158-159; Tucker 19:299; Logan 34:41.)
156	Superior (Tin Cup)	Henry A. Alker and Elliott S. McCurdy, Trustees for Estate of Emma H. Rose, 220 Montgomery Street, San Francisco	20,29 30	10N	11E	MD	On Mother Lode one mile east of Diamond Springs. Located in 1867, active around 1888-90, and again in 1900. Three parallel veins strike north and dip 45° east with slate footwall and greenstone hanging wall. Ore yielded $4.80 to $15 per ton. Developed by 250- and 700-ft. adits and 400-ft. inclined shaft. Ore treated in 10-stamp mill. (Irelan 88:187-189; DeGroot 90:172; Crawford 94:124; 96:159; Storms 00:94; Tucker 19:299; Logan 34:41.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Syracuse	Not determined	33	9N	13E	MD	One mile east of Omo Ranch. Active in 1908.
	Tapioca						See California Consolidated.
157	Taylor (Idlewild)	W. N. Guth, 2024 N. New England Avenue, Chicago, Illinois	21,30	12N	10E	MD	(Irelan 88:168-171; DeGroot 90:176; Preston 92:205; Crawford 94:113; 96:145; Tucker 19:299; Logan 22:209,210; 34:41-42; herein.)
	Tennessee-Nashville						See Nashville.
	Threlkel (Winton)	United States of America (withdrawn for Federal reservoir site)	16	11N	8E	MD	Immediately east of the Zantgraf mine one mile south of Rattlesnake Bridge. Active 1924-26 and 1937. Several thin veins of good grade in granodiorite. Developed by adit. Ore treated in 2-stamp mill. (Logan 26:418; 38:255.)
	Tin Cup						See Superior.
	Treat	Helen B. Treat, 93 San Carlos Avenue, Sausalito	4	9N	13E	MD	Two and one-half miles north of Grizzly Flat. Active prior to 1888 and again in 1896. Vein in granodiorite strikes north and dips west. Developed by 100-ft. vertical shaft and adits. (Irelan 88:178; Crawford 96:159; Tucker 19:299.)
158	Trench (Yellowjacket)	Not determined	18	13N	11E	MD	In Quartz Canyon one mile south of Volcanoville. Active prior to 1894. A vein strikes north. (Crawford 94:125; 96:159; Tucker 19:299.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	True Consolidated		6,7	10N	11E	MD	See Placerville Gold Mining Company. (Irelan 88:180-181; Crawford 94:125; 96:144.)
159	Tullis (Diamond)	Starlight Mining Co., 2626 Baker Street, San Francisco	1	9N	10E	MD	One mile southeast of El Dorado. Active 1896. A 2½ ft. vein in quartz porphyry strikes north and dips 30° east. Developed by 200-ft. inclined shaft and 175 ft. of drifts. (Crawford 96:159-160; Tucker 19:299.)
160	Union (Springfield)	El Dorado Mining Company, P.O. Box 1724, Spokane 7, Washington	12	9N	10E	MD	(Hanks 86:43; Irelan 88:167; Storms 00:92; Tucker 19:299; Logan 22:209-210; 26:418-419; 34:42-43; 38:251-253; herein.)
	Union Consolidated						See Alpine.
	Unity						See Pine Hill.
	U. S.Grant (New Deal)	Not determined	32	11N	12E	MD	North of Mt. Danaher. Active during 1870's when ore treated in 10-stamp mill; prospected in 1936. A 1- to 4-ft. vein contained two ore shoots. Developed by shaft and 100-ft. crosscut adit with drifts 400 ft. north and 200 ft. south. (Logan 38:253.)
	Utah Apex						See Montezuma.
161	Valdora	Not determined	16	9N	13E	MD	Adjoining Mt. Pleasant mine on the south, one-half mile west of Grizzly Flat. Active around 1888. Granite wall rock. Developed by 110-ft. vertical shaft.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Valdora (continued)						(Irelan 88:178; Crawford 96:161.)
	Van (Vann)	V. M. Fishback, Box 164, Georgetown	2	12N	10E	MD	Three-quarters of a mile north of Georgetown. Long idle (Crawford 94:126; 96:161; Tucker 19:300.)
162	Vandalia	G. L. Tripp, Route 1, Box 5, Shingle Springs	19	9N	10E	MD	(Irelan 88:172-173; DeGroot 90:178; Crawford 94:126; Storms 00:96-98; Logan 22:301; 26:419; 38:254; herein.)
163	Vandergreft	Karl Skuja, El Dorado	26	9N	10E	MD	Three miles north of Nashville. Active prior to 1914. Developed by 250-ft. inclined shaft and 100-ft. adit. Ore treated in 10-stamp mill. (Tucker 19:300.)
164	Van Hooker		6 36	10N 11N	11E 10E	MD MD	See Placerville Gold Mining Company. (Irelan 88:181-182; DeGroot 90:173; Crawford 96:161.)
	Vann						See Van.
165	Veerkamp (Gold Coin)	Ray A. Veerkamp, Garden Valley	33	12N	10E	MD	(Logan 34:37-38; 38:247; herein.)
	Victoria	Not determined	4	10N	9E	MD	Four miles northwest of Rescue near Boulder mine. Active 1924-26. Vein developed by 30-ft. shaft and 50-ft. drift. Ore which yielded $8 per ton, was treated in 2-stamp mill. (Logan 24:178; 26:419.)
	Volo						See Shaw; also see Volo mill in Copper section.

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Wagner	Camilla D. Heald, 624 South 13th Street, San Jose	11	8N	10E	MD	Near Lotus; prospected in 1925. (Logan 26:419.)
166	War Eagle	H. J. Picchetti, 1115 Fairview Avenue, San Jose	24	11N	10E	MD	On Mother Lode one mile southeast of Kelsey. Ore occurs in pockets in 18-in. vein. Developed by 80-ft. shaft and 150-ft. adit. (Logan 34:43.)
	Webber						See Placerville Gold Mining Company.
	Webster	Georgetown Lumber Company, Georgetown	31	13N	11E	MD	In Quartz Canyon two miles south of Volcanoville. Active around 1894. A 1-ft. vein between slate and serpentine strikes north 15° east and dips 55° southeast. Developed by 200- and 300-ft. crosscut adits. (Crawford 94:126; 96:161; Tucker 19:300.)
167	Welch	Dollie K. Goss and H. S. McDaniel, 315 Park View Terrace, Oakland	7	12N	10E	MD	Half a mile northeast of Greenwood. Active 1894-96. A 3- to 8-ft. vein in slate. Ground was sluiced and then vein was developed by 100-ft. inclined shaft and 150-ft. crosscut adit. (Crawford 94:126; 96:161; Tucker 19:300.)
	White Bear						See Polar Bear.
	White Bear		36	11N	10E	MD	See Placerville Gold Mining Company. (Irelan 88:182; Crawford 96:161.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
168	White Owl	Kate E. Hennesey, 515 Park Avenue, New York, N.Y.	23	11N	11E	MD	Near Red Bird Creek two miles southeast of Mosquito Camp. Active 1938. A $1\frac{1}{2}$- to 3-ft. vein in granodiorite strikes northeast; ore yielded up to $65 per ton. Developed by 65-ft. inclined shaft. Ore treated in 2-ton Gibson mill. (Logan 38:254-255.)
	Wiedebush	Not determined	20	13N	11E	MD	Two miles south of Volcanoville. Active 1920-26. A 70-ft. ore shoot 3 to 4 ft. wide developed by adit. Ore treated in small roller mill. (Logan 21:428; 26:419.)
	Wild Cat	Not determined	20,21, 28,29	12N	10E	MD	Two miles northwest of Garden Valley. Active in 1926.
	Wild West						See Rainbow.
	Wilhelm and Last Chance	W. J. White, Cool	25	12N	8E	MD	Four miles southeast of Auburn. Long idle. (Tucker 19:300.)
	Wiltshire	Elizabeth M. Green, c/o W. A. Green, 205 Courthouse, Sacramento	36	9N	10E	MD	A "pocket" mine near Nashville. Active around 1926. (Logan 26:419.)
	Winton						See Threlkel.
	Woodland						See Orum.
	Woodside - Eureka						See Beebe. (Preston 92:200; Crawford 94:126; 96:161; Tucker 19:300.)

LODE GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Yellowjacket						See Trench.
	Young Harmon		7	10N	11E	MD	See Placerville Gold Mining Company.
169	Zantgraf (Montauk Consolidated, Zentgraf)	United States Government (land withdrawn for Federal reservoir)	16	11N	8E	MD	(Irelan 88:200-202; DeGroot 90:178; Crawford 96:161-162; Tucker 19:300; Logan 22:209-210; 24:8; 26:419-420; 38:255-257; herein.)
	Zentgraf						See Zantgraf.

PLACER GOLD

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Allen dredge	Allen Gold Dredge Company, Lotus					Operated suction dredge on Bacchi Ranch near Lotus during 1945-47.
	Alveoro	Not determined	3,10	10N	11E	MD	Drift mine one-half mile northeast of Smith's Flat. Active around 1908. Channel deposit 100 to 300 ft. wide and 6 to 30 ft. deep; gravel is partially cemented and capped by andesite. Developed by 4000-ft. adit and 400- and 500-ft. inclined shafts. (Tucker 19:300-301.)
	Amelia		9	13N	11E	MD	Two miles east of Volcanoville. Developed by 600-ft. adit. See also Two Channel Mining Company which worked property many years ago. (Logan 38:251.)
	Armstrong and Roberts	Not determined	29	9N	13E	MD	Drift mine at Henry Diggings three miles south of Grizzly Flat. Active 1894. A northeast-striking channel 60 ft. wide and 5 ft. thick is developed by 600-ft. adit. (Crawford 94:101-102; 96:132; Tucker 19:301.)
	Avansino	Alida L. Avansino, Route 3, Box 196, Placerville	29	10N	12E	MD	Drift mine near Pleasant Valley. Active around 1893; prospected in early 1930's. Channel and bench gravels developed by 107-ft. shaft with 57-ft. north drift on 90-ft. level and 307-ft. south drift on 107-ft. level. (Logan 38:216-217.)
170	Badger Hill	G. W. McMillen, 1342 Gilman Street, Berkeley	28	11N	12E	MD	At Badger Hill seven miles east of Placerville on Tertiary channel of South Fork of American River. Some rich gravel interbedded with rhyolite tuff mined by drifting and sluicing. (Lindgren 11:170; Tucker 19:301.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Ball	Not determined		8N	13E	MD	Drift mine three and one-half miles southeast of Omo Ranch. Active around 1935. Well-cemented gravel 80-ft. wide. Developed by 1,250-ft. adit to channel and 600-ft. drift south. (Logan 38:217.)
	Barker dredge	Barker Corporation, Patterson					Operated dragline dredge on the Explorers property in 1942. (Averill 46:255.)
	Barnes						See Channel Bend.
171	Bella Vista	Harold C. Welch et al., P.O. Box 146, Sutter Creek	8	8N	12E	MD	Drift mine three miles northeast of Aukum. Active 1936. Two channels, one above other, trend northeast, lie on granodiorite and capped by rhyolite. Contained $1 to $1.50 per yard. Developed by 400-ft. drift adit, raises, and 200-ft. drift. Gravel treated in washing plant and sluice. (Logan 38:218-219.)
	Bend						See Channel Bend.
	Benfeldt (Rogers)	Not determined	10	10N	11E	MD	Drift mine at Smith's Flat. Active 1888-96 and 1916-19. Channel trends north, averages 5 ft. in thickness and is 50 to 120 ft. wide; slate bedrock; gravel yielded $2 to $8 per ton. Developed by 750-ft. inclined shaft and drifts. Gravel treated in 10-stamp mill and 150-ft. sluice. (Irelan 88:197-198; DeGroot 90:179; Crawford 96:133; Lindgren 11:177; Tucker 19:301.)
	Big Canyon dredge	Big Canyon Dredging Company, Fresno					Operated 3-cu. yd. dragline dredge on Big Canyon and Deer Creeks from 1937 to 1942. (Logan 38:363; Averill 46: 255.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Bitters						See Two Channel Mining Company.
	Black Gold	Alida L. Avansino, Route 3, Box 196, Placerville	29	10N	12E	MD	Drift mine in Pleasant Valley district adjoining Hinds drift mine. Active 1930-31 and 1936, with an output of several thousand dollars. Bench of fine loose gravel developed by 60-ft. shaft with drifts 100 ft. west, 280 ft. north, and 127 ft. east. Gravel treated in two 10-stamp mills. (Logan 38:223.)
	Blacklock	Not determined	8,17	10N	11E	MD	Drift and hydraulic mine one mile northeast of center of Placerville. Active 1896. A 60-ft. bank with 4-ft. thick channel hydraulicked and later worked by drifting. (Crawford 96:134; Tucker 19:301.)
	Blair	E. W. Meyers, Box 336, Camino	10,11	10N	12E	MD	Two miles southeast of Camino. Prospected and drilled in 1890. Channel is 300 to 400 ft. wide. (DeGroot 90:179; Crawford 94:104.)
	Blakeley						See Maple Leaf.
	Boles	United States of America (withdrawn for Federal reservoir site)					On American River three miles upstream from Rattlesnake Bridge. In 1924-25, gravels from bed of river excavated by barge-mounted suction pump which discharged to sluice boxes. Diver directed the nozzle. (Logan 26:438.)
	Bottle Hill	Not determined	27	13N	10E	MD	Two miles northwest of Georgetown. Isolated patch of auriferous gravel capped by andesite mined by drifting many years ago. (Lindgren 11:169.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Boulder	Pilot Hill Mining Co., Pilot Hill	6	11N	9E	MD	At Pilot Hill. Old channel remnant 20 to 40 ft. deep worked by power shovel, and gravel treated in stationary washing plant in 1936. Yield was 13 to 60 cents per yard. (Logan 38:243.)
	Brass						See Murzo.
	Bronson dredge	W. B. Bronson, Georgetown					Operated dragline and non-floating washing plant on Browning Ranch in 1947.
172	Buckeye Hill (Flora)	W. E. Colby, 2416 East Flora, Stockton	12	13N	10E	MD	On Buckeye Point two miles west of Volcanoville. Active 1890's and early 1930's. Channel trends northeast;is as much as 1,000 ft. wide with alternating layers of gravel and cemented material. Mined by hydraulicking and drifting. Developed by 400-ft. bedrock adit. Gravel yielded $1.33 per ton. (Crawford 94:105; 96:136.)
	Buck's Bar	Not determined	6	9N	12E	MD	Northeast of Buck's Bar on North Fork of Cosumnes River. A gravel deposit 8 to 16 ft. deep worked by dragline in 1936. (Logan 38:227.)
	Burt Alley	O.S. Strawn, Box 255, Georgetown	29,30	13N	11E	MD	Three miles south of Volcanoville. Gravel deposit worked around 1894. (Crawford 94:105; 96:136.)
	California Mohawk						See Fairplay.
	Canyon Creek						See Gold Bug. (Crawford 94:105; Tucker 19:301.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Carpender	Not determined					Worked in conjunction with Kumfa drift mine 1911, 1913, 1919, 1928, and 1936; see also Kumfa.
	Carrie Hale	Not determined	34	9N	13E	MD	Drift mine at Henry's Diggings, three miles south of Grizzly Flat. Active around 1894. Channel extends northeast, is 60 ft. wide, and up to 5 ft. thick. Developed by 400-ft. bedrock adit; mined in 12-ft. breasts. Pay streak in blue gravel on granite bedrock. (Crawford 94:105-106; 96:136.)
	Cedar Ravine	Not determined	17	10N	11E	MD	In Cedar Ravine one mile south of Placerville. Active prior to 1890. Well-cemented gravel was mined and treated in 10-stamp mill. (DeGroot 90:180.)
173	Cedar Spring	Not determined	17	10N	11E	MD	Drift mine at Cedar Ravine one mile south of Placerville on Green Mountain channel. Active 1870's to around 1901. Channel is crooked, 300 to 600 ft. wide, and pay gravel is 4 to 6 ft. thick; some benches. A deep channel with benches also mined. Developed by 900-ft. south-southeast adit and 75-ft. incline. Also a lower aidt. (Lindgren 11:175-176.)
	Cement Hill	Not determined	27,28 33,34	13N	10E	MD	Drift mine on Cement Hill three miles northwest of Georgetown. Active 1894-96. An east-west channel prospected by 750- and 600- ft. adits. (Crawford 94:106; 96:137.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER · NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
174	Channel Bend (Barnes, Bend, Gray Eagle Bar, McCall)	M. T. Duffey, 6009 Santa Fe Avenue, Huntington Park	5	13N	11E	MD	Drift mine two miles northeast of Volcanoville by Middle Fork of the American River. A bend in a channel of the Tertiary Middle Fork worked through 136-ft. shaft and 200- and 300-ft. drifts during the 1890's. (Crawford 96:137; Tucker 19:301.)
	Chili Ravine	Not determined	19	10N	11E	MD	Drift mine in Chili Ravine two miles south of Placerville. Active 1870-90 and 1912-15. Channel trends north; gravel is well cemented and 3 to 12 ft. thick. Developed by a 1200-ft. crosscut adit, 700-ft. drift adit, and air raises. (Irelan 88:194-196; DeGroot 90:180; Crawford 94:106.)
	Christian	Not determined					Drift mine at Henry Diggings three miles south of Grizzly Flat. Worked intermittently since 1949 by I. H. Campion, Somerset. See also Slide and Payne drift mines.
	Claghorn (Growers)	Not determined		8N	12E	MD	Drift mine on Cedar Creek two miles south of Fairplay. Active around 1896. A northeast-trending Tertiary channel with granite bedrock developed by 200-ft. adit. (Crawford 96:138.)
	Clark	Not determined	16	10N	11E	MD	Drift mine on south side Texas Hill, one mile southeast of Placerville. Active during early days of gold rush. Several benches on tributary of Tertiary South Fork of American River developed by north-trending adit several hundred feet long. (Lindgren 11:178-179.)
	Clarksville dredge	F. O. Bohnett, Santa Barbara					Operated dry land dredge near Clarksville in 1939.

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Confederate	Not determined	8	8N	12E	MD	Drift mine two and one-half miles southwest of Fairplay. Active 1896. Two adits, 250 and 200 ft. in length driven in Tertiary channel on granite bedrock. (Crawford 96: 138; Tucker 19:301.)
	Cooley	Not determined	17	13N	11E	MD	Drift mine at Volcanoville. Prospected by Wm. Ogle in 1934 and 1936; some gold output.
175	Coon Hollow (includes Excelsior claim)	Not determined	18,19	10N	11E	MD	Drift and hydraulic mining one mile south of Placerville. Drifted from 1852 to 1861 and hydraulicked from 1861 to 1871. Gold output from this area totaled $10,000,000. Gravel yielded about $1 per cubic yard. Accumulated tailings being mined for aggregate; see Stone section. See also Excelsior. (Whitney 80:119; Lindgren 11:172, 174.)
	Danaher						See Roundabout.
	Diamond Springs		24,25	10N	11E	MD	At Diamond Springs. Extensive deposit of Tertiary gravel; portion mined by hydraulicking many years ago. (Lindgren 11:170.)
	Dividend	Not determined	3	10N	9E	MD	On Pichem Creek four miles northwest of Rescue. Active 1880's, 1890's and 1912-15. Extensive deposit of gravel 1 to 3 ft. thick on granite bedrock worked by ground sluicing. (Crawford 94:108; 96:139; Tucker 19:301.)
	Dorsey	Not determined	17	8N	13E	MD	One mile northeast of Indian Diggings. Long idle.
	Eagle	Not determined	31	9N	13E	MD	One mile northwest of Omo Ranch. Long idle.

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	El Dorado Dredge	El Dorado Dredging Corporation, Greenwood					Operated $1\frac{1}{2}$-cu. yd. dragline dredge on Greenwood, Coloma, Rock Canyon, and Irish Creeks, 1940-42 and 1948. (Averill 46:255.)
	El Dorado Water and Deep Gravel Mining Company						Operated hydraulic and drift mines in the Placerville area including the Excelsior. Held claims in Coon Hollow. See Coon Hollow and Excelsior.
	Excelsior	Placerville Gold Mining Company, Box 191, Placerville	18,19	10N	11E	MD	At Coon Hollow one mile south of Placerville. About $5,000,000 recovered from this claim by drifting and hydraulicking between 1852 and 1871. Mined by drifting during 1907-11. Gravel was treated in 10-stamp mill. Tributary of Tertiary South Fork of American River contained three pay streaks. See also Coon Hollow. (Whitney 80:98,114,119; Lindgren 11:172,174-175.)
	Fairplay (California Mohawk)	Not determined	34	9N	12E	MD	Drift mine just east of Fairplay. Long idle. At one time this property was owned by the California Mohawk Mining Company. (Tucker 19:301.)
	Ferriera		29	10N	12E	MD	One mile south of Newtown. Prospected in 1930 when 135-ft. shaft sunk in search of gravel. (Logan 38:229.)
	Flora						See Buckeye Hill.
	Fort Jim		23	10N	11E	MD	Drift mine four miles southeast of Placerville. Active 1913-15.

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Fossati (Tunnel)	Not determined	17	10N	12E	MD	Drift mine one and one-half miles south of Camino. Active intermittently 1930-36. Two channels, of Tertiary South Fork of American River, the lower being 25 to 200 ft. wide developed by adits and raises. (Logan 38:230.)
	Franklin (Tockey)	Placerville Gold Mining Company, Box 191, Placerville		10N	11E	MD	Drift mine two and one-half miles east of Placerville. Active around 1896 and in 1907. A Tertiary channel of the South Fork of the American River developed by 1400-ft. drift in channel. Gravel sent through 10-stamp mill and 100-ft. sluice. (Crawford 96:140-141; Tucker 19:301.)
	French Corral dredge	French Corral Gold Dredging Company, Sacramento					Operated dragline dredge at Brown's Bar on Middle Fork American River in 1946.
	General dredge	General Dredging Corporation, Natoma					Operated 1½ cu. yd., and 2 cu. yd. dragline dredges near Coloma and near Shingle Springs during 1939-42. Averill 46:255.)
	Gignac	George H. Wickes, 24 Olivene, Placerville	16	10N	11E	MD	Drift mine at Texas Hill two and one-half miles southeast of Placerville. Active during 1890's. (DeGroot 90:180; Tucker 19:301.)
	Giltedge	Not determined	9	8N	12E	MD	Two and one-half miles south of Fairplay. Active 1896. Tertiary channel capped with sand and clay contains coarse gold on bedrock. Developed by 300-ft. adit. (Crawford 96:142; Tucker 19:302.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Gold Bug (Canyon Creek)	Not determined	34	13N	10E	MD	Two miles north of Georgetown just north of Georgia Slide mine. Accumulated hydraulic mine tailings, seam deposit detritus, and some virgin gravel were intermittently worked by several concerns from around 1896 to 1934. Material was excavated by draglines and sent through trommel and sluices. (Crawford 94:105; 96:142-143; Tucker 19:301; Logan 22:301; 26:438-439.)
	Gold Channel Mining Company						Controlled drift and hydraulic mines in the Volcanoville-Kentucky Flat area that formerly were operated by the Two Channel Mining Company; which see. (Tucker 19:302.)
	Gray Eagle Bar						See Channel Bend.
	Gray Eagle Cliff			13N	11E	MD	At Volcanoville. Active about 1894. West-trending channel was worked through adit. Pay gravel is well cemented. (Crawford 94:112; 96:143; Tucker 19:302.)
	Great Bend dredge	Great Bend Corp., Lotus					Mined gold-bearing gravels at Lotus with gas shovel in 1931.
	Greenhorn dredge	Greenhorn Dredging Company, Auburn					Operated 2 cu. yd. dragline dredge on Middle Fork Cosumnes River near Youngs in 1940-42 and on Barkley property in 1947. (Averill 46:255.)
	Green Mountain	Not determined	17,20	10N	11E	MD	Drift mine on south side of Texas Hill two and one-half miles southeast of Placerville. The Green Mountain channel, a tributary of the Tertiary South Fork of the

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Green Mountain (continued)						American River, was mined through a 1700-ft. adit. (Lindgren 11:175-176.)
176	Grizzly Flat	Not determined	15	9N	13E	MD	Drift and hydraulic mine at Grizzly Flat. Active 1880's, 1896, and 1914-20. A north-trending channel on granite bedrock first worked by hydraulicking and later by drifting. Developed by 550-ft. drift. (Crawford 94:112-113; 96:144; Tucker 19:302; Logan 26:439.)
	Growers						See Claghorn.
	Harnish	Not determined		8N	12E	MD	Drift mine on Fairplay channel one and one-half miles south of Fairplay. Active 1896. Channel 4 to 5 ft. thick with much mica; developed by adit. (Crawford 96:144.)
177	Hayward (Indian Diggings)	Theresa Garibaldi, Amador City	18	8N	13E	MD	Drift and hydraulic mine at Indian Diggings. Active around 1896. A 275-ft. bank with 159 ft. of gravel; limestone bedrock. (Crawford 96:145, 147; Lindgren 11:181; Tucker 19:302.)
	Henness dredge	M. G. Henness and S. Legate, Georgetown					Operated dragline dredge near Georgetown during 1946-47.
	High Tunnel	Not determined	33	11N	11E	MD	Drift mine three miles northeast of Placerville and north of White Rock Canyon. Active in early days and 1926. Channel of Tertiary South Fork of the American River developed by 500-ft. adit. (Logan 26:439.)

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Hinds (Los Angeles)	Alida L. Avansino, Route 3, Box 196, Placerville	29	10N	12E	MD	Drift mine one mile northwest of Pleasant Valley. Discovered 1927; active early 1930's. Bench gravel deposit lying on rhyolite developed by 48-ft. shaft and 200-ft. northwest drift. (Logan 38:233.)
	Hook and Ladder						See Toll House. (Averill 46:255-256.)
	Hoosier Gulch dredge	Hoosier Gulch Placers, Sacramento					Operated dragline dredge in Logtown Ravine in 1939 and near Shingle Springs in 1945 and 1947.
	Hope	Not determined		13N	11E	MD	Northeast of Volcanoville. A Tertiary channel deposit mined prior to 1892. (Preston 92:206; Crawford 94:113.)
	Hope						See Landecker.
	Horseshoe dredge	Horseshoe Dredging Company, Youngs					Operated dragline dredge near Youngs on Cosumnes River 1938-40. (Logan 38:363; Averill 46:256.)
	Horseshoe Flat	Not determined		10N	12E	MD	A drift mine two and one-half miles east of Newton; Long idle. (Tucker 19:302.)
	Hutchinson and Woodburn	Not determined	26	9N	12E	MD	A drift mine at Slug Gulch three miles northeast of Fairplay. Active 1926. (Logan 26:439.)
	Indian Diggings						See Hayward. (Lindgren 11:181.)
	Indian Diggings Creek	Not determined	18	8N	13E	MD	Hydraulic mine on Indian Creek near Indian Diggings. Active around 1896. Bedrock is limestone. (Crawford 96:147.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Ingram dredge	W. E. Ingram, Gridley					Operated dragline dredge at Horseshoe Bar on Middle Fork of American River, 1940-42. (Averill 46:256.)
	Irish Creek	Irish Creek Mining Company, Georgetown					Operated non-floating washing plant near Georgetown in 1940. (Averill 46:256.)
	Irish Slide	Not determined	33	9N	13E	MD	Drift mine at Henry Diggings three miles south of Grizzly Flat. Intermittently worked since 1949 in conjunction with Payne and Christian drift mines by I. H. Campion, Somerset. See also Payne and Christian drift mines.
	Jerusalem	Not determined		10N	11E	MD	One and one-quarter miles east of Placerville. Prospected bench gravel deposit by hydraulicking in 1894. (Crawford 94:114; 96:147.)
	Jinkerson and Arditto	W. A. Jinkerson, 61 Del Monte Avenue, Los Altos	18	8N	13E	MD	Drift mine at Indian Diggings. Active 1913-17 and in 1926, developed by adit several hundred feet along. (Logan 26:439.)
178	Jones Hill	Not determined	20,29	13N	10E	MD	Hydraulic mine at Jones Hill five miles northwest of Georgetown. Active around 1892 and again in 1907. Channel trends northeast with slate bedrock; gravel 8 ft. thick. A 200-ft. bank hydraulicked. Equipped with 1200- and 1440-ft. flumes. (Preston 92:204; Lindgren 11:169.)

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Kates (Norris)	Not determined		13N	11E	MD	Drift and hydraulic mine one and one-half miles east of Volcanoville. Active prior to 1894 and again in 1896 when prospected by Two Channel Mining Company. West-trending Tertiary channel deposit, 250-ft. bedrock adit and drifts. Gravel treated in stamp mill. (Crawford 94:114-115; 96:147,160.)
179	Kenna	Not determined	15	13N	11E	MD	Drift and hydraulic mine one mile northeast of Kentucky Flat. Active prior to and during 1896 when operated by Two Channel Mining Company. Some work done around 1922. Main or white channel hydraulicked; blue channel developed by 1500-ft. adit. Gravel well cemented and gold was coarse; gravel treated in 10-stamp mill. See also Two Channel Mining Company. (Crawford 96:160; Logan 38:251.)
180	Kentucky Flat	Not determined	22	13N	11E	MD	Drift and hydraulic mine at Kentucky Flat. Active 1894-1902 and again in 1933. Main or white channel hydraulicked in pit with 25-ft. bank; blue channel developed by 625-ft. adit and 80-ft. shaft. See also Two Channel Mining Company. (Crawford 94:115; 96:147,150; Logan 38:251.)
	Knight dredge	Knight Placer Mining Company, Georgetown					Operated dragline dredge in Georgetown area in 1947 and 1948.
	Kumfa (Kum Fa)	Not determined	15	10N	11E	MD	Drift mine at Smith's Flat. Active 1911-13, 1928 and 1936. Developed by 631-ft. inclined shaft; see also Carpender. (Lindgren 11:173; Tucker 19:302.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	Kum Fu						See Kumfa.
	Landecker (Hope)	Not determined	20,21	10N	11E	MD	Drift mine one and one-half miles southeast of Placerville. Active in early 1900's and in 1925 and 1935. (Lindgren 11:178.)
	Last Chance	Not determined	28	9N	13E	MD	At Henry's Diggings two miles northeast of Omo Ranch. Long idle.
	Last Chance						See Try Again.
	Lemroh dredge	Lemroh Mining Company, San Francisco					Operated dragline dredge during 1939-40. (Averill 46:256.)
	Levenson			8N	13E	MD	Hydraulic mine one mile southeast of Fairplay. Active around 1896 when 50-ft. bank was mined. Gravel treated in 120-ft. sluices. (Crawford 96:148.)
	Lincoln dredge	Lincoln Gold Dredging Company, Lincoln					Operated dragline dredge in 1937.
181	Linden	Not determined	16,17	10N	11E	MD	Drift mine in Cedar Ravine one and one-half miles southeast of Placerville. Active 1882-94 when $130,000 was produced from gravel yielding $3.25 per yard. Deep Blue Lead channel developed by 4000-ft. adit with numerous

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Linden (continued)						drifts along benches and two shafts. Gravel treated in 10-stamp mill. (Irelan 88:196-197; DeGroot 90:179; Crawford 94:115-116; 96:148; Lindgren 11:177-178; Tucker 19:302.)
	Little Big Hole		30	9N	13E	MD	On Middle Fork Cosumnes River five miles northeast of Fairplay. Active 1926 when river diverted and 250-ft. adit worked. (Logan 26:440.)
	Lord and Bishop dredge	Lord and Bishop, 1853 North Eldridge, North Sacramento					Operated 3 cu. yd. dragline dredge on Greenwood and Carson Creeks in 1949 and 1950.
	Los Angeles						See Hinds.
	Lotus Bar		18	11N	10E	MD	Gravel deposit on South Fork of the American River at Lotus was mined by several concerns during 1930's. Gravels were excavated by power shovel or bulldozer and sent through washing plants. (Logan 38:235; 237.)
182	Lyon	Not determined	9,16	10N	11E	MD	Drift mine one mile southeast of Smith's Flat and two miles east of Placerville. Active prior to 1900 with a total output of $1,400,000. Deep Blue Lead channel with a number of winding benches developed by 2 shafts and drifts. (Lindgren 11:172,177.)
	Maple Leaf (Blakeley)	Not determined	11 or 12	10N	11E	MD	Two miles west of Camino near Five Mile House. Active in 1880's. From 1932 to 1935, operated as relief project and gave employment to 100 men. About $20,000

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Maple Leaf (continued)						produced during this period by hydraulicking and sluicing.
	Matherly dredge	E. B. Matherly, Lotus					Operated suction dredge on American River near Coloma from 1947-1952.
	McCall						See Channel Bend. (Crawford 94:116-117; 96:150.)
	McCoy and Butler dredge	J.W.S. Butler, Sacramento					Operated dry land dredge in 1941.
	McKim	Not determined		9N	13E	MD	Drift mine near Henry Diggings. Prospected in 1926 when 100-ft. adit and 20-ft. raise driven. (Logan 26:440.)
	McQueen and Downing dredge	McQueen and Downing, Weaverville					Operated dragline dredge on Carson Creek in 1940. (Averill 46:256.)
	Mead dredge	Mead Company, 208 Fremont Street, San Francisco					Operated dragline dredge at Cherokee Bar in 1949.
	Mississippi	Not determined		13N	11E	MD	Drift mine one and one-half miles east of Volcanoville. Active around 1894. Tertiary channel deposit developed by 240-ft. adit. (Crawford 94:117-118; 96:150.)
	Molkey	Not determined		8N	12E	MD	Hydraulic mine one mile southeast of Fairplay. A northeast Tertiary channel lies on granite bedrock; much clay present. (Crawford 96:150-151.)

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Mooney	Rhyolite, Inc., c/o E. C. Connella, 111 Sutter Bldg., San Francisco 4	15	10N	12E	MD	Drift mine two miles northeast of Newtown. Active 1894-96. (Crawford 94:118; 96:151; Tucker 19:302.)
	Morgan						See Two Channel Mining Company.
	Mount Gregory	Not determined	9	13N	11E	MD	Hydraulic mine three miles east of Volcanoville. Active 1896 and 1912 when 20- to 25-ft. bank with 8 ft. of cemented gravel was mined. (Crawford 96:151; Tucker 19:302.)
	Murzo (Brass)	W. E. Colby et al., 2416 East Flora, Stockton	12	13N	10E	MD	Drift mine on Buckeye Point one mile west of Volcanoville. Active around 1894 when 150-ft. adit driven in slate bedrock. (Crawford 94:119; 96:151.)
	Negro Hill		32	11N	11E	MD	At Negro Hill three miles northeast of Placerville. Tertiary gravel deposit mined by drifting and hydraulicking many years ago. (Lindgren 11:177.)
	Nelson dredge	R. N. Nelson, Sacramento					Operated dragline dredge near Shingle Springs in 1946.
	Norris						See Kates.
	Novis		9	13N	11E	MD	See Two Channel Mining Company. (Logan 38:251.)
	Old Empire	Not determined	32	9N	13E	MD	At Henry's Diggings one and one-half miles north of Omo Ranch. Long idle.

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	One Spot (Sailor Jack)	Not determined	17,18	10N	12E	MD	Drift mine one mile south of Camino. Active in early days when $40,000 produced and again 1934-38. Two channels of the Tertiary South Fork American River one above other developed by 500-ft. adit with drifts and raises. Gravel yielded up to $8 per yard. (Logan 38: 242.)
	Orloma dredge	Orloma Company, Placerville					Operated $1\frac{1}{4}$ cu. yd. dragline and dry-land washing plant on Indian Creek during 1941-42. (Averill 46:256.)
183	Pacific Channel (Zimmerman)	Not determined	34	11N	13E	MD	Drift mine one-half mile west of Pacific House. Active from around 1915 to early 1920's. Tertiary channel of South Fork American River trends southwest on granite bedrock and capped by andesite. Developed by several adits, one 1000 ft. in length. Gravel treated in barrel gravel mill. (Tucker 19:303; Logan 20:428-429; 26: 440.)
	Pacific Dredge	Pacific Dredging Co.					Operated floating bucket-line dredge with $7\frac{1}{2}$ cu. ft. buckets on Middle Fork American River at Mammoth Bar, 1914-18. (Logan 18:29.)
	Patterson	Not determined	20	8N	13E	MD	Drift mine two miles southeast of Indian Diggings. Active around 1935.
184	Payne	Mable Cole et al., 28 Crescent Drive Placerville	28	9N	13E	MD	Drift mine at Henry Diggings three miles south of Grizzly Flat. Active 1894; intermittently worked since 1949 by I. H. Campion, Somerset, in conjunction with Irish Slide and Christian drift mines. Tertiary channel deposit with 1 to 3 ft. of gravel. Developed by adit. See also Irish Slide and Christian drift mines.

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	T.	R.	B & M	REMARKS
	Payne (continued)						(Crawford 94:120; 96:153; Tucker 19:302.)
	Pilot Hill dredge	Pilot Hill Mining Company					Operated dry-land dredge in Shingle Springs-Rescue area in 1935-36.
	Pleasant Valley	Not determined		10N	12E	MD	Tertiary channel deposit near Pleasant Valley prospected in 1894. (Crawford 94:121.)
	Potts and Maginess			10N	12E	MD	Drift mine three-fourths mile east of Newton, long idle. (Tucker 19:302.)
	Quartz Canyon	Not determined		13N	11E	MD	One mile south of Volcanoville in Quartz Canyon. Accumulated debris worked in a self-shooting reservoir during the 1890's. (Crawford 96:155.)
185	Rising Hope	Roy C. Bishop, Box 70, Placerville	15	10N	11E	MD	Drift mine at Texas Hill three miles southeast of Placerville. Active 1910-20 and in 1929. Channel of Tertiary South Fork American River trends north, is 2 to 7 ft. thick, and up to 700 ft. wide. Near junction of Newton and Smith's Flat channels. Developed by 3500- and 3000-ft. drifts. Equipped with 50-ton barrel mill. (Tucker 19:303; Logan 20:429; 26:440.)
	River Pine dredge	River Pine Mining Company, Ltd., 141 Battery Street, San Francisco					Operated dragline dredge near Nashville in 1941-42, near Plymouth in 1946 and near Diamond Springs in 1949-50. (Averill 46:256.)
	Rivera	Not determined	16	10N	11E	MD	Drift mine at Texas Hill two miles southeast of Placerville. Active prior to 1900 and around 1905. Channel of

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Rivera (continued)						Tertiary South Fork American River developed by 900-ft. adit, raises, and drifts. (Lindgren 11:178; Tucker 19:302.)
	Rocky Bar	Daily Journal Co., c/o R.C. Hoeschlaub, Suite 920, 621 S. Hope Street, Los Angeles	25	9N	12E	MD	On Middle Fork Cosumnes River near Cosumnes Copper mine and limestone deposit. Active early 1920's when potholes in limestone were worked for placer gold with pumps and derricks. (Logan 26:440.)
	Rogers						See Benfeldt.
	Roundout (Danaher)	Not determined		10N	11E	MD	Two and one-half miles northwest of Smith's Flat. Prospected around 1919. A 400-ft. inclined shaft and 600-ft. drift driven east in attempt to find gravel channel. (Logan 20:429-430; 26:438.)
	Rubicon	Volcanoville Mining Company, Room 910, Crocker Bldg., San Francisco	15	13N	11E	MD	Drift and hydraulic mine two and one-half miles west of Volcanoville. Active 1880's and 1890's. First worked as hydraulic mine. Gravel deposit 4 ft. thick and 27 ft. wide developed by 110-ft. drift. (Crawford 96:156.)
	Sailor Jack						See One Spot.
	Sailor Slide	Not determined	3 34	12N 13N	10E 10E	MD MD	One mile north of Georgetown in Georgia Slide area. Active 1919-22.
	Santa Rosa	Not determined	16	13N	11E	MD	Drift mine on Hopkins Creek one mile east of Volcanoville. Active 1894-96. Channel trends southwest; developed by

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Santa Rosa (continued)						718-ft. adit. (Crawford 94:122; 96:156.)
	Schreiber dredge	A. L. Schreiber, Los Angeles					Operated dragline dredge near Coloma in 1942.
	Seils dredge	Seils Brothers, Auburn					Operated dry-line dredge near Auburn in 1939.
	Slug Gulch	Clifford Smith, Somerset, and others	25	8N	12E	MD	Hydraulic mine at Slug Gulch three miles east of Fairplay. Active in early days, during the 1900's, and again about 1930. Bedrock is partly limestone. (Lindgren 11:181.)
	Snow	Not determined		10N	12E	MD	Hydraulic mine one and one-half miles northeast of Newton. Active around 1896 when cemented gravel was mined in two pits. (Crawford 96:156-157.)
	Solari Tunnel		20	10N	12E	MD	Portion of Ventura drift mine, which see; prospected in 1935 through 351-ft. adit in search of bench gravel. (Logan 38:250.)
	Spanish Bar dredge	Inter-American Enterprises, Ltd., Sacramento					Operated dragline dredge at Spanish Bar on Middle Fork American River during 1950-51.
	Starbuck	F. M. Starbuck, Rescue	16,17	10N	9E	MD	Two miles northwest of Rescue. Gravel lying on decomposed granite intermittently mined by dragline late 1930's and early 1940's. (Averill 46:256.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Stewart	Not determined	20	10N	11E	MD	Drift mine two miles southeast of Placerville between Chili Ravine and Weber Creek. Active 1880's and early 1890's. (DeGroot 90:180; Crawford 94:123; 96:157; Tucker 19:303.)
186	Texas Hill	Not determined	16	10N	11E	MD	Drift mine at Texas Hill two miles east of Placerville. Active around 1894. Channel of Tertiary South Fork of American River trends northwest, pay gravel 1 to 3 ft. thick, and capped by 120 ft. of andesite. Developed by 1500-ft. drift, 75-ft. incline, and 157-ft. shaft; breasts up to 100 ft. in width. Gravel treated in 10-stamp mill and 100-ft. suice. (Crawford 94:124-125; 96:159; Lindgren 11:173.)
187	Tiedemann (Tiederman)	Not determined	27	13N	11E	MD	Drift and hydraulic mine one and one-half miles south of Kentucky Flat. Active prior to 1896 and from 1896 to 1902 when operated by Two Channel Mining Company; again active 1932-1934. Main or white channel hydraulicked while blue channel developed by two adits, one 100 ft. in length. See also Two Channel Mining Company. (Crawford 96:160; Logan 38:251; Averill 46:257.)
	Tiederman						See Tiedemann.
	Tipton Hill	Not determined	34 3	13N 12N	11E 11E	MD MD	At Tipton Hill seven miles northeast of Georgetown. North-trending channel deposit of tributary of Tertiary Middle Fork of American River mined by drifting and hydraulicking many years ago. (Lindgren 11:168.)
	Tockey						See Franklin.

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
188	Toll House (Hook and Ladder)	Charles Fossetti, Placerville	10	10N	11E	MD	Drift mine at Smith's Flat. Active prior to 1890, during the 1890's, and from 1918 to 1932. Deep Blue Lead and Gray Lead channels developed by 152-ft. shaft, raises, and several thousand feet of drifts. (DeGroot 90:179; Crawford 96:159; Tucker 19:303; Logan 20:428; 23a:45; 26:439; Averill 46:255-256.)
	Try Again (Last Chance)	Not determined	15	10N	11E	MD	Drift mine three miles east of Placerville. Active around 1896. Channel of Tertiary South Fork of American River trends northwest; developed by 1500-ft. bedrock adit and 213-ft. shaft. (Crawford 96:159; Lindgren 11:179; Tucker 19:303.)
	Tunnel						See Fossati.
	Twin Forks dredge	Twin Forks Dredging Company, 1831 P Street, Sacramento					Operated dragline dredge on North Fork Cosumnes River near Youngs in 1949.
	Two Channel Mining Company						Operated drift and hydraulic mines in the Volcanoville-Kentucky Flat area until about 1908. These properties included the Amelia, Bitters, Kates or Norris, Kenna, Kentucky Flat, Morgan, Novis, Tiedemann, and Wilton claims. (Crawford 96:160; Logan 38:251; Averill 46:257.)
	Uncle Sam	Not determined		8N	12E	MD	Drift mine two miles south of Fairplay. Active 1896. Two adits run through bedrock to Tertiary channel. (Crawford 96:160.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Union	Not determined	3 33	10N 11N	11E 11E	MD MD	Drift mine two miles east of Placerville. Channel of Tertiary South Fork of American River trends southwest, 6 in. to 4 ft. thick, 400 ft. wide, and has 100-ft. andesite capping. Developed by 285- and 412-ft. shafts. (Tucker 19:303.)
189	Unity	Not determined	3,4	10N	11E	MD	Drift mine at Wisconsin Flat, two miles northeast of Placerville. Active early 1890's. Deep Blue Lead channel courses southeast; up to 12 ft. thick, capped with benches 200 ft. wide. Developed by 1700-ft. drift and inclined shaft. Gravel treated in 10-stamp mill and 160-ft. sluice. (Crawford 94:125-126; 96:161.)
	Uno	Not determined	9	8N	12E	MD	Drift mine three miles south of Fairplay. Active prior to 1896. Channel developed by 350-ft. adit partly in granite, 50-ft. drift and raise. (Crawford 96:161.)
	Van Dyke dredge	Van Dyke, Modrell, and Warner, Ione					Operated 3/4 cu. yd. dragline dredge on Gordon property in 1941. (Averill 46:257.)
	Varozza dredge	C.H.M. Mining Co., Sacramento					Operated dragline dredge during 1946-47.
190	Ventura (includes Solari Tunnel)	Robert Patterson, Bedford Avenue, Placerville	20	10N	12E	MD	Drift mine on north side ridge between Webber Creek and Pleasant Valley south of Newton. Active 1930's and early 1940's. A 1300-ft. adit in volcanic ash driven south in attempt to reach channel. (Logan 38:250,254; Averill 46:257.)

PLACER GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	W.W.	Georgetown Lumber Co., Georgetown	27	13N	10E	MD	Drift mine at Cement Hill four miles north of Georgetown. Active 1894. Channel coursing southeast. Prospected by 400-ft. bedrock adit. (Crawford 94:126-127; 96:161.)
	Wabash Deep Channel	Not determined	26	13N	10E	MD	Drift mine three miles north of Georgetown. Active 1856-67, 1907, and 1920. Channel developed by 4 shafts and 350-ft. bedrock adit. (Logan 20:430.)
	White Rock			9N	8E	MD	One mile west of Clarksville. Gravels in Carson Creek mined by dragline in 1925-26. (Logan 26:440.)
	White Rock diggings	Not determined	31,32	11N	11E	MD	At White Rock Canyon three miles northeast of Placerville. Deep Blue Lead channel, mined by hydraulicking many years ago, yielded $5,000,000. (Lindgren 11:172, 176-177.)
	Wilton	Not determined		13N	11E	MD	Drift mine near Otter Creek eight miles northeast of Georgetown. Active around 1894. South-trending Tertiary channel 600 ft. wide developed by 700-ft. adit. See also Two Channel Mining Company. (Crawford 94:126; 96:160,161.)
	Worthington	Not determined		13N	11E	MD	Drift mine northeast of Volcanoville. Active around 1892 when gravel yielding 16 cents per cubic yard was mined. (Preston 92:206; Crawford 94:126.)
	Wulff	W. C. Wulff, Rescue	8	10N	9E	MD	Five miles northwest of Rescue. Active 1938-46. Surface placer worked by small-scale methods. (Logan 38:255; Averill 46:257.)

PLACER GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Yellowjacket	Not determined	18	8N	13E	MD	Drift mine near Indian Diggings. Active 1926-27 and 1930.
	Zimmerman						See Pacific Channel. (Tucker 19:303.)

SEAM GOLD

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Beattie and Parsons Consolidated						See Georgia Slide. (Preston 92:203; Crawford 94:102; 96:133; Tucker 19: 281.)
	Blasdel	Not determined	35	13N	10E	MD	At Dark Canyon 2 miles north of Georgetown. Seam belt 2000 feet long trends N. (Logan 34:44.)
	Blue Rock		34	13N	10E	MD	See Georgia Slide. (Preston 92:203; Crawford 94:104; Tucker 19:282.)
	Bower	Not determined	7	12N	10E	MD	At Greenwood. Active prior to 1892 with total output of $2,000,000. A 30- to 100-ft. zone of slate and schist contains quartz seams. (Preston 92:204; Crawford 96: 136; Tucker 19:282.)
	Carrol	Not determined	18	12N	10E	MD	On east slope of Greenwood Hill. Seam zone hydraulicked in open pit 40 ft. wide. (Logan 34:45.)
191	Castile	Not determined	27	12N	10E	MD	One mile east of Garden Valley. Two quartz veins in seam zone 18 ft. wide hydraulicked in early days. (Logan 34:45.)
192	Cedarberg (Drury)	Byron W. Bacchi et al., Lotus	1 36	12N 13N	9E 9E	MD MD	On east side American Canyon 2 miles northeast of Greenwood. First worked in 1868; active in 1890's and early 1920's. Veins and veinlets in slate trend N. and dip E.; yielded much specimen gold. Hydraulicked at first, later mined through a 318-foot inclined shaft with levels at 100, 200, and 300 feet. (Crawford 94:106; 96:137;

SEAM GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Cedarberg (Drury) (continued)						Tucker 19:282; Logan 26:413; 34:45.)
	Cranes Gulch (Whitesides)	Not determined	15	12N	10E	MD	One mile south of Georgetown. Active prior to 1874 when $100,000 produced from open pit 250 ft. long, 150 ft. wide, and 70 ft. deep. (Logan 34:45.)
	Drury						See Cedarberg.
	Fairweather and Fairweather No. Extension						See Spanish Group.
	Fisk						See Joseph Skinner.
	French (Nagler)	Marcus Peterson et al., Box 331, Suisun	13	12N	9E	MD	Just west of Greenwood. Active prior to 1874 and again during 1890's; total output of more than $500,000. Zone of quartz seams trends N. up to 200 ft. wide. Worked by hydraulicking in pit 80 ft. deep and 600 ft. long. Also developed by shallow shaft. (Preston 92:204; Crawford 94:110; 96:141; Tucker 19:286; Logan 34:35.)
193	French Hill	Harriett Taylor, 1612 E. 7th Street, Long Beach 4	36	13N	9E	MD	One mile southwest of Spanish Dry Diggings. Active around 1894. Quartz seams and 1½-ft. vein trend NW and dip NE. Mined in open cuts and material treated in 800-ft. sluice and 10-stamp mill. Also developed by 100-ft. shaft and 100-ft. adit. Also prospected for asbestos.

SEAM GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	French Hill (continued)						See Asbestos section. (Crawford 94:110; 96;141; Tucker 19:286; Logan 26:404; 34:47; 38:207.)
194	Georgia Slide (Beattie and Parsons Consolidated, Blue Rock, Mulvey Point, Pacific)	Kelsey Lumber Company, 585 Main Street, Placerville	3 34	12N 13N	10E 10E	MD MD	(Tucker 19:286; Logan 24:8; 26:437; Knopf 29:48-49; Logan 34:36; herein.)
	Gilt Edge (Revenge Consolidated)	Not determined	20	12N	10E	MD	One mile southeast of Greenwood. Worked by hydraulicking in early days. (Logan 38:231.)
195	Golden State	Mamie E. Forni, Georgetown	29	13N	10E	MD	Just west of Jones Hill 4 miles northwest of Georgetown. Active early 1890's. Quartz seams in belt 200 to 300 ft. wide mined in open cut and sluiced. (Preston 92:204; Crawford 94:111-112; 96:143; Tucker 19:287.)
	Grit						Upper portion of deposit worked as seam deposit. See Lode gold section.
196	Hart	Daniel Gellerman, 4524 Brand Way, Sacramento	27	12N	10E	MD	(Logan 34:47; 38:233; herein.)
	Hines-Gilbert						See in Lode gold section.

SEAM GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Hodge and Lemon	Not determined	6	10N	11E	MD	At north end of Quartz Hill one mile north of Placerville. Seam zone mined in open pit 40 ft deep. (Logan 34:47.)
	Joseph Skinner (Fisk, Porphyry)	Not determined	7	10N	11E	MD	On Mother Lode one mile north of Placerville. Active 1896-98, 1901-03 and around 1932. Total output nearly $100,000. Ore in thin quartz seams and small bunches in dike rock and Mariposa slate. Originally worked by hydraulicking. Developed by 232-ft. adit and drifts. (Crawford 96:140; Tucker 19:285-286; Logan 34:28,45.)
	Lincoln	Not determined	34	13N	10E	MD	One mile northwest of Georgetown. Active 1896 and again 1926. A seam belt 300 ft. wide strikes north. Developed by 100-ft. cut and 3 adits, 150, 60, 110 ft. in length; 900 ft. of sluices employed. (Crawford 96:148-149; Tucker 19:289; Logan 26:414.)
	Little Chief	William Barklage et al., 5713 State Avenue, Sacramento	26,35	13N	10E	MD	On Canyon Creek two miles north of Georgetown. Active 1894. Seams developed by 130- and 240-ft. adits; ore treated in 1-stamp mill. (Crawford 94:116.)
197	Mameluke (Mameluke Hill)	L. L. Clark, 6 Arbor Way, Lafayette	3	12N	10E	MD	One mile north of Georgetown. Active prior to 1880 with total output of not less than $2,000,000. Coarse gold recovered from alluvium and seams in slate. (Whitney 80:118; Preston 92:203; Tucker 19:290.)
	Mameluke Hill						See Mameluke.

SEAM GOLD (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Morning Star group	Mary A. Fitzgerald, Box 35, Ivanhoe, California	2	12N	10E	MD	In seam belt 1 mile northeast of Georgetown. Active around 1926. Yielded about $75,000. (Logan 26:415.)
	Mulvy Point		35	13N	10E	MD	See also Georgia Slide. (Tucker 19:292)
	Nagler						See French.
	New Garibaldi	Henry Henze, 4571-A Chateau, St. Louis, Missouri	12	12N	9E	MD	One mile west of Greenwood. Active 1896. An 8-ft. deeply weathered vein in slate strikes northwest and dips northeast; ore shoot about 400 ft. long. Developed by 170-ft. crosscut adit and shallow shafts. Ore treated in 25-ton Kinkaid mill. (Crawford 96:152; Tucker 19:293.)
	Pacific		34	13N	10E	MD	See also Georgia Slide. (Crawford 96:153; Tucker 19:292.)
	Parsons						See Georgia Slide.
	Porphyry						See Joseph Skinner.
	Revenge Consolidated						See Gilt Edge.
	St. Lawrence	Not determined					Yielded $23,000 by hydraulicking. (Logan 34:47.)

SEAM GOLD (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
198	Sam Martin	Claude A. Harris, 1011 Broadway, Vallejo	6,7	12N	10E	MD	One mile north of Greenwood. Active 1894-96. A 20-ft. zone of quartz seams in slate strikes northwest and dips 60° northeast. Upper portion sluiced, lower portion mined through 80-ft. adit. Was equipped with 200-ft. flume. (Crawford 94:122; 96:156.)
	Sliger						See Lode gold section.
	Snow Flake						See Spanish group.
199	Spanish Group (Snow Flake, Fairweather and Fairweather No. Extension)	E. F. Pease, 400 N. Michigan Avenue, Chicago, Illinois	12	12N	9E	MD	One mile northwest of Greenwood. Mined in early days: prospected in 1930's. Seam belt 100-ft. wide hydraulicked, yielded $13,600. Developed by drift adit. (Logan 34:47.)
	Swift and Bennett	Not determined	11	12N	10E	MD	Just south of Georgetown. Active 1870's, when rich ore produced. (Logan 34:47.)
	Waun	State of California	24	13N	9E	MD	One mile northwest of Spanish Dry Diggings. A seam belt 50 ft. wide mined by hydraulicking and later by underground methods. (Logan 34:47.)
	Whitesides						See Cranes Gulch.

IRON

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	LOCATION T.	LOCATION R.	LOCATION B & M	REMARKS
200	Chaix	Roy Chaix et al., Box 87, Placerville	14	8N	9E	MD	One and one-half miles south of Latrobe. A lens of magnetite and hematite as much as 25 ft. wide crops out for a distance of 60 ft. Much silica present. Similar prospect 1 mile west. (Logan 26:441.)
	Gutenberger	Not determined					Five miles east of Diamond Springs. A prospect containing hematite. (Logan 26:441.)
201	Reliance	E. G. Wendt, Box 792, Rio Vista	18	10N	9E	MD	Three miles north of Bass Lake. Two magnetite veins $4\frac{1}{2}$ ft. wide are in coarse-grained gabbro, which also contains disseminated magnetite. Developed by 50-, 218-, and 312-ft. shafts, now caved. (Aubury 06:297; Boalich 22:110; Logan 26:441.)
	Simons	Roy Chaix et al., Box 87, Placerville	13	8N	9E	MD	Adjoins Chaix prospect. A prospect containing magnetite and hematite. (Logan 26:441.)

LEAD

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	LOCATION T.	LOCATION R.	LOCATION B & M	REMARKS
	Hazel Creek						A gold mine. Ore contains considerable amount of galena. See Lode gold section.

MANGANESE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	LOCATION T.	LOCATION R.	LOCATION B & M	REMARKS
202	Alderson	Albert Earl Harris et al., 69 Clay Street, Placerville	16 17	10N	11E	MD	One and one-half miles southeast of Placerville. Zone of arkosic sandstone 150 ft. long and cemented by black manganese oxide interbedded with Tertiary volcanic beds. Assays as high as 25 percent manganese. (Trask and others 43:11; 50:51.)
	Buffalo Hill	Not determined	10	12N	10E	MD	Just west of Georgetown. A prospect; manganese oxide in metasediments. Assays 11.7 percent manganese. (Trask and others 43:111; 50:51.)
203	David	Not determined	10	12N	10E	MD	Just west of Georgetown. Parallel bands of pyrolusite and psilomelane in NE-striking SE-dipping beds of chert and quartzite. Averages 5 to 10 percent manganese. Developed by open cuts. (Trask and others 43:111; 50:51-52.)
	Double E	Cecilia Simpson, 4029 Kuhule Street, Oakland	12	9N	10E	MD	Two miles southeast of El Dorado. Small low-grade deposit. (Trask and others 43:111; 50:52.)
204	Martinez	Martinez Gold Mines Company, P. O. Box 61, El Dorado	13	9N	10E	MD	Three miles southeast of El Dorado near Martinez gold mine. Two NE-striking lenses 2 ft. wide contain rhodonite and black manganese oxide. Country rock chert and schist. (Trask and others 43:111; 50:52.)
205	Mocettini	Robert D. Domecq, et al., Route 1, Box 39, Shingle Springs	13	8N	9E	MD	Two and one-half miles east of Latrobe. Greenstone stained with black manganese and iron oxides, developed by open cut. (Trask and others 43:111; 50:52-53.)

QUICKSILVER

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Amador						See Bernard.
206	Bernard (Amador)	J. L. Schneider, Sloughhouse	4	8N	10E	MD	By Fanny Creek 2 miles west of Nashville. Active during 1860's, some quicksilver ore produced; prospected 1903, again in 1917. Cinnabar with pyrite occurs interstitially in slate and quartzite. Developed by 75-ft. vertical shaft and 117-ft. adit. (Crawford 94:359; Aubury 03:190; Bradley 18:42; Tucker 19:306; Logan 26:445.)
	Shingle Springs	Not determined					Traces of cinnabar found 5 miles south of Shingle Springs. (Logan 26:445.)

TUNGSTEN

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Balderson	Not determined	10	12N	11E	MD	Three miles south of Balderson Station near Rock Creek. Minor amounts of scheelite in fine-grained tactite.
	Bear Creek						See Comeback Consolidated.
207	Bucks Bar	Martin Williams, Somerset	12	9N	11E	MD	Two miles west of Buck's Bar by North Cosumnes River. Small amounts of scheelite in contact metamorphic rock.
	Caldor						See Grizzly Flat.
208	Comeback Consolidated (Bear Creek)	Ajax Consolidated Mines Company, c/o Bruce Thompson, First National Bank Building, Reno, Nevada	4,	11N	11E	MD	(Logan 38:365; Averill 43:318; herein.)
209	Grizzly Flat (Caldor, Pierce, Sciaroni)	North portion: Caldor Lumber Company, Diamond Springs. Central portion: Horace Pierce, Sacramento; leased by E. L. Wilbur, North Sacramento. South portion: Americo and Columbus Sciaroni, Grizzly Flat	32 5	10N 9N	13E 13E	MD MD	Herein.

TUNGSTEN (CONT.)

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
210	Pacific House	Not determined	22	11N	13E	MD	One mile west of Pacific House on north bank of American River. Scheelite in tactite. Developed by open cut.
	Pierce						See Grizzly Flat.
	Pioneer-Lilyama		3	11N	9E	MD	Copper mine. Minor amounts of scheelite observed in tactite. See under Copper. (Cox and others 48:45.)
	Rubicon	Not determined	18	13N	12E	MD	Just east of the junction of the Middle Fork American and Rubicon Rivers. Scheelite found both in El Dorado and Placer Counties.
	Sciaroni						See Grizzly Flat.
211	Williams	Blanche Williams, Placerville	1	9N	11E	MD	Herein.

ASBESTOS

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Contraband (El Dorado Copper Mining Company.)	Not determined	24	12N	10E	MD	See also under Copper. (Aubury 06:262; Logan 26:404; 38:207; herein.)
	French Hill	Harriett Taylor, 1612 E. 7th Street Long Beach 4	36	13N	9E	MD	See also Seam gold section. (Logan 26:404; 38:207; herein.)

DIMENSION STONE

MAP NO	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
212	Sierra Placerite	Sierra Placerite, Route 2, Box 252, Placerville	29	10N	12E	MD	Herein.

DOLOMITE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Larkin mine	Bernard B. Ball, 122 Bedford Avenue, Placerville	29	10N	11E	MD	See also Lode gold section. (Logan 47:233.)

LIMESTONE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	LOCATION T.	LOCATION R.	LOCATION B & M	REMARKS
	Alabaster Cave						See Rattlesnake Bridge.
	Auburn Lime Products Company						See Rattlesnake Bridge in text.
213	Browns Bar	Ideal Cement Company, 310 Sansome Street, San Francisco	4	12N	9E	MD	Deposit of bluish-gray limestone near Browns Bar by Middle Fork of American River. Apparently never worked. (Clark 54:465.)
214	Buckeye Canyon	Ideal Cement Company, 310 Sansome Street, San Francisco	34	13N	9E	MD	Deposit of bluish-gray limestone in Buckeye Canyon by Middle Fork American River. Apparently never worked. (Clark 54:465.)
	California Rock and Gravel Company						See Cool-Cave Valley.
215	**Cool-Cave Valley** (California Rock and Gravel Co., Cowell-Cave Valley, Mountain Quarries)	South 2/3 owned by Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco North 1/3 owned by Ideal Cement Company, 310 Sansome Street San Francisco	6,7, 18	12N	9E	MD	(Whitney 65:281; Hanks 84:107; Crawford 94:391-392; Lindgren 94:3; Crawford 96:628; Aubury 02:17; 06:68; Tucker 19:304, 390-391; Logan 21:43,432; Young 25b:13-16; Logan 26:442-443; 27:282; Laizure 27:208; 29:251; Logan 38:277,280; 47:222,224-226; Bowen and Crippen 48:73,80; Clark 54:438-465; herein.)
	Cosumnes						See Slug Gulch.
	Cowell-Cave Valley						See Cool-Cave Valley.

LIMESTONE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
216	Diamond Springs	Diamond Springs Lime Corp., Diamond Springs	27,28	10N	11E	MD	(Crawford 94:391: 96:628; Logan 26:443-444; 38:274-276; 47:226-230; herein.)
217	El Dorado	El Dorado Limestone Company, Shingle Springs	15	9N	9E	MD	(Young 25a:1001-1002; Logan 26:441-442; 38:276-277; 47:230-231; herein.)
218	Indian Diggings	Theresa Garibaldi, Amador City, et al.	17,18	8N	13E	MD	Extensive deposits crystallized limestone at Indian Diggings and one mile to SW. (Whitney 65:281; Logan 26:444; 38:273; 47:231; herein.)
219	Marble Valley (Schwalin)	Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco	8,17	9N	9E	MD	(Whitney 65:281; Logan 24:442; 38:280; 47:231-232; herein.)
	Mountain Quarries						See Cool-Cave Valley.
220	Rattlesnake Bridge (Alabaster Cave, Rattlesnake Bar)	Semon Lime Company, Auburn	15	11N	8E	MD	(Aubury 06:65-68; Tucker 19:304; Logan 21:432; 24:8; 26:442-443; 38:273-274; 47:222, 223-224; Clark 54:461; herein)
	Schwalin						See Marble Valley.
	Semon Lime Company						See Rattlesnake Bridge.

LIMESTONE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
221	Slug Gulch (Cosumnes)	Clifford Smith, Somerset	24,25, 26	9N	12E	MD	(Logan 47:231; herein.)
	Vertin Lime Company						See Rattlesnake Bridge in text.
222	West Cool-Cave Valley	Ideal Cement Company, 310 Sansome Street, San Francisco	12	12N	8E	MD	One mile west of Cool-Cave Valley limestone by Middle Fork American River. A northwest-trending lens 450 ft. long and 50 ft. wide of bluish-gray, high-calcium limestone in metasediments. Old stone lime kiln nearby. See also Cool-Cave Valley herein. (Clark 54:460.)

SILICA

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Brandon	Not determined	36	9N	9E	MD	Near Brandon Corner. Massive quartz vein 10 to 35 ft. wide crops out about 250 ft. (Logan 26:445; Sampson and Tucker 31:437.)
	Coon Hollow	Leased by Harms Bros. Construction Company, Sacramento	18	10N	11E	MD	At Coon Hollow 1 mile south of Placerville. Quartz cobbles produced from hydraulic mine tailings prior to 1926. At present deposit used as source of aggregate material. (Logan 26:445; Sampson and Tucker 31:445.)
	Snow	Placerville Gold Mining Company, c/o L. F. S. Holland, Box 191, Placerville	32	11N	11E	MD	At White Rock Canyon 4 miles northeast of Placerville. Massive quartz vein 25 ft. wide exposed 600 feet along strike; mined for silica at one time. (Logan 26:445-446; Sampson and Tucker 31:437-438.)

SLATE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Buck	Pacific Minerals Co., Ltd., 339-10th Street, Richmond	36	11N	10E	MD	Adjoins Chili Bar slate mine. Active in 1880's. (Irelan 88:200; Logan 26:448.)
223	California-Bangor Slate Company	c/o Breed & Robinson, Financial Center Building, Oakland	2,3, 10, 11,14	11N	10E	MD	One mile northwest of Kelsey. Active prior to 1915. (Tucker 19:306; Logan 26:448.)
	California Slate Quarry	Not determined	23,25	11N	10E	MD	Three miles north of Placerville on north side of American River. Active around 1889. Slate of poor quality because of presence of pyrite. (Irelan 89:283; Aubury 06:150; Tucker 19:306; Logan 26:448)
	Chadbourne						See El Dorado Slate Products Company.
224	Chili Bar	Pacific Minerals Co., Ltd., 339-10th Street, Richmond	36	11N	10E	MD	(Irelan 88:199-200; Crawford 94:401-402; Aubury 06:150; Tucker 19:306; Logan 26:448; 38:365; Bowen and Crippen 48:68; herein.)
	El Dorado Big Tunnel Company						Near Chili Bar. Some development work around 1894. (Crawford 94:401.)
	El Dorado Slate Products Company (Chadbourne)	Not determined	6	10N	11E	MD	On south side Big Canyon 1½ miles north of Placerville. Roofing slate produced from several quarries during 1920's. Finished material sent across canyon via overhead cable. Waste sold for roofing granules. (Logan 26:449.)

SLATE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION SEC.	LOCATION T.	LOCATION R.	LOCATION B & M	REMARKS
	Eureka Slate Quarry (Sierra Slate Corp.)	Not determined		11N	10E	MD	One mile south of Kelsey. Active from around 1886 to about 1926. Large amounts of dimension slate mined from quarry with 200-ft. face and up to 200 ft. deep. Slate delivered to Placerville via 13,000-ft. aerial tramway. (Aubury 06:150-152, 153; Tucker 19:306-308; Logan 22: 602; 26:449-450; 38:365.)
	Landeker	Not determined		11N	10E	MD	Near Kelsey. Produced roofing slate during 1880's. (Irelan 88:199.)
225	Losh	Not determined	25	11N	10E	MD	One-half mile north of Chili Bar. Active 1890, 1921-24, and 1937. Dimension slate produced from open pit 50 ft. deep and 40 ft. wide. (Logan 23a:602; 26:450.)
	Pacific Minerals Company, Limited						See Chili Bar. (Logan 38:365.)
226	San Francisco Slate Company	Not determined	26	11N	10E	MD	On north side American River opposite Chili Bar. Roofing slate produced during 1890's from several quarries. (Crawford 94:401.)
	Sierra Slate Corporation						See Eureka Slate Quarry.

SOAPSTONE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
227	Bernett	D. P. Bernett, Shingle Springs	23	9N	9E	MD	Herein.
	Brandon (Richardson)	Not determined		9N	9E	MD	Near Brandon Corner. Active in 1920; 1 carload produced. A 2-ft. lens of gray soapstone developed by short crosscut adit and drift. (Logan 20:432; 26:451.)
228	Bryant	Bryant Ranch, Shingle Springs	9,10	8N	9E	MD	One-half mile north of Latrobe. Small amounts of soapstone mined by Industrial Minerals and Chemical Company, Berkeley, in 1954 for use as insecticide carrier.
	Darlington	Not determined		10N	11E	MD	Three miles southeast of Placerville near Webber Creek. Active in 1880's, sawed slabs produced. Lens of massive soapstone up to 25 ft. wide and 130 ft. long developed by open cuts. (Logan 26:451.)
	Harold	Not determined					An undeveloped prospect 4 miles from Shingle Springs. (Logan 26:451.)
229	Hayden	Mark Hayden Shingle Springs; was leased by Industrial Minerals and Chemical Company, Berkeley	7	9N	10E	MD	Herein.
230	Pacific Minerals (Swift)	Rufus Swift, Shingle Springs; leased by Pacific	35	9N	9E	MD	(Logan 20:433; Logan 26:451; herein.)

SOAPSTONE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Pacific Minerals (continued)	Minerals Company, Ltd., 337 - 10th Street, Richmond					
	Richardson						See Brandon.
	Rossi						See Shingle Springs.
	Shingle Springs (Rossi)	Not determined		9N	10E	MD	One mile east of Shingle Springs. Active 1919-28 when soapstone shipped for use as roofing coating. Lens of green soapstone in serpentine developed by open pit. (Logan 20:432-433; 26:451.)
	Swift						See Pacific Minerals.

STONE

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
231	Anderson Pit	H. C. Anderson, Meyers	20	12N	18E	MD	One mile north of Meyers by U.S. Highway 50. Sand from decomposed granite quarried for use as road metal and aggregate in batching plant. Material excavated by bulldozer and loaded into dump trucks. Also, gravel produced from Truckee River near Meyers.
	Butler Pit	Archibald Butler, Meyers	16	12N	18E	MD	Two miles north of Meyers by Truckee River. River gravel and sand from decomposed granite excavated for use as aggregate and road metal.
232	Cold Springs Sand and Gravel Company	Jerry Brown, Placerville	9	10N	10E	MD	Herein.
	El Dorado County Road Department						Coarse sand mined for use as road metal and fill from several pits in decomposed granite in Deer Valley-Rescue-Shingle Springs area. It also is obtained from just south of Lotus and a few miles east of Aukum. Serpentine from Hummingbird Ranch near Garden Valley (see Hummingbird Ranch) and just north of Four Corners is used as road metal.
233	Harms Pit	Harms Brothers Construction Co., Sacramento	18	10N	11E	MD	Herein.
234	Highways, Division of	State of California	12	11N	10E	MD	Sand pit 1 mile northwest of Coloma by State Highway 49. Coarse sand derived from decomposed granite and granodiorite used as road fill and in asphalt mix. An extensive

STONE (CONT.)

MAP NO.	CLAIM, MINE, OR GROUP	OWNER NAME, ADDRESS	LOCATION				REMARKS
			SEC.	T.	R.	B & M	
	Highways, Division of (continued)						quarry several acres in extent with 30-ft. faces is worked by power shovel; material is screened, and loaded into dump trucks.
235	Hummingbird Ranch	M. A. Nichols, Garden Valley	32	12N	10E	MD	Serpentine quarry 1 mile west of Garden Valley. Serpentine, used as road metal by El Dorado County Road Department, excavated by bulldozer and loaded into dump trucks. Open cut 200 ft. long, 30 ft. wide, and 10 ft. deep.

Recommendations for a

National Minerals Policy

from the WESTERN GOVERNORS MINERAL POLICIES CONFERENCE
November 7-8, 1955

and the WESTERN GOVERNORS MINING ADVISORY COUNCIL
November 9, 1955

at SACRAMENTO, CALIFORNIA

(Reprint)

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CONTENTS

Page

Foreword 597

The Conference Story 599

A Proposed National Minerals Policy 601

Officers and Delegates, Western Governors Mining Advisory Council 623

The Conference Leaders 626

The Conference Registrants 629

Report of the Committee on Research 637

Goodwin J. Knight
Governor

State of California
GOVERNOR'S OFFICE
SACRAMENTO

FOREWORD

The Western Governors Mineral Policies Conference of November 7-8, 1955, in Sacramento, California, and the subsequent meeting of the Western Governors Mining Advisory Council, combined to produce an excellent list of recommendations for the development of a national minerals policy—the objective of the conference.

These recommendations, as submitted herewith, have been formally presented to each of the western states governors, and the Governors of South Dakota and Alaska, by the members from their respective states on the mining advisory council. In the interests of national defense and the economy of the Nation, it is hoped that each governor soon will be able to approve these recommendations with a minimum of reservations—so that they may become the recommendations of the Western Governors Conference to the Nation.

With the submission of this report, the work of the Western Governors Mineral Policies Conference hereby ends; and all conference committees are discharged with honor. The work of the Western Governors Mining Advisory Council, however, is only beginning, for this council should be the major element in assisting the western governors to represent a strong case for a sound national minerals policy.

Goodwin J. Knight

Goodwin J. Knight
Governor of California

THE CONFERENCE STORY

The formulation of national mineral policy recommendations aimed at developing and maintaining a healthy mineral industry in the western United States was the objective of the Western Governors Mineral Policies Conference held in Sacramento, California, November 7 and 8, 1955.

Leaders of the mining industry and state officials of the western United States have been aware for some time that the economic conditions in the mining industry were not good.

Recognizing that the permanent welfare of the mining and mineral consuming industries of the western states, South Dakota and Alaska is strategically important to national defense and vital to the economy of the United States of America, Governor Goodwin J. Knight of California issued the call for the conference after consultation with, and the approval of, Governor Charles H. Russell of Nevada, who is the Chairman of the Western Governors Conference.

Approximately 3,000 invitations were issued by Governor Knight to members of the mining industry throughout the western states, South Dakota and Alaska. Samuel H. Williston of Palo Alto, California, the 1955 Chairman of the Western Governors Mining Advisory Council, issued a call to the delegates of the advisory council to attend the general conference and to participate in a regular council meeting following the general conference for the purpose of studying the recommendations of the general conference in order to produce formal recommendations for a national minerals policy from the advisory council to the western governors.

Governor Knight designated Mr. Williston and DeWitt Nelson, the California Director of Natural Resources, to serve as cochairmen of the conference.

Approximately 500 persons assembled in Sacramento for the conference, which formally opened on Monday morning, November 7th, with a general session in the auditorium of the Masonic Temple. Governor Knight presented the keynote address at the opening general session. U. S. Senator Thomas H. Kuchel of California spoke on the subject "Building a Permanent Domestic Mining Industry," and Governor Robert E. Smylie of Idaho addressed the group on the subject "The Nation's Need for a Strong Mineral Industry." The governors of six western states were present at the conference. They included J. Bracken Lee of Utah; Stephen L. R. McNichols, the acting Governor of Colorado; Russell of Nevada; Milward L. Simpson of Wyoming; and Smylie of Idaho. During the afternoon of November 7th, the conference participants divided into 18 commodity section meetings to discuss the problems of mineral commodities in the following groups: Aggregates-Clay-Talc, Antimony, Asbestos, Cement, Chrome, Coal, Copper, Fluorspar, Gold, Lead-Zinc-Silver, Manganese, Mercury, Molybdenum, Phosphate, Potash, Rare Earths-Thorium, Tungsten, and Uranium-Vanadium. Each of the commodity sections was directed to consider problems under the following subjects: Taxes, Lands and Water, Mineral Economics, Research, and Public Information. At the conclusion of the commodity section meetings, reports of each section were prepared and duplicated overnight for distribution on the morning of November 8th to all conference participants. The November 8th morning conference activity divided the conference participants into five policy section groups under the headings of Taxes, Lands and Water, Mineral Economics, Research, and Public Information. The findings of the commodity sections were analyzed at this time and decisions reached in each of these groups on recommendations for national mineral policies within the subject area of the group.

Preconference committees, paralleling the conference commodity and policy section organizations, were formed several months in advance of the conference in the participating states. These committees explored their particular areas of interest through correspondence, meetings and personal discussions. The problems defined, remedial action suggested and supporting data obtained from this preconference committee work did much to assist the deliberations at the conference.

The closing general session of the conference was held on the afternoon of November 8th and was opened with an address by U. S. Senator George W. Malone of Nevada, whose subject was "The International Problems and Their Relation to the American Mining Industry." Following his address, the reports from the morning policy sections were presented to the conference.

These reports then went to the Western Governors Mining Advisory Council which met on November 9th to consider the reports and from them to draw up the formal recommendations of the advisory council to the western governors. There follows herewith the recommendations of the Western Governors Mining Advisory Council to the western governors.

A PROPOSED NATIONAL MINERALS POLICY

RECOMMENDED TO THE WESTERN GOVERNORS
THE WESTERN GOVERNORS MINING ADVISORY COUNCIL

As developed at the

WESTERN GOVERNORS MINERAL POLICIES CONFERENCE
Sacramento, California, November 7-9, 1955

INDEX

Page

e 602

uction 603

al Economics 607
. Gold 607
. Silver 607
. Lead and Zinc 608
. Copper 608
. Molybdenum 608
. Fluorspar 608
. Uranium-Vanadium 608
. Rare Earths and Thorium 609
. Quicksilver 609
. Tungsten 610
. Chrome 610
. Manganese 611
. Antimony 611
. Asbestos 612
. Coal 612
. Aggregates-Clay-Talc 612

and Water 613

615

ch 617

Information 618

le Solutions Considered in Developing Recommendations for the
ous Mineral Commodities 618

PREFACE

The Western Governors Mining Advisory Council was formed in February of 1953 by Governor Earl Warren of California, now Supreme Court Justice Warren, at the suggestion of former Governor Douglas McKay of Oregon, now Secretary of the Interior.

The powers of the Western Governors Mining Advisory Council are severely limited. They may make recommendations only to the governors of the western states and the governors are in no way bound to follow such recommendations. The council is made up of men appointed by the respective governors in whom they have confidence. It may vary in number as each governor may desire. It has been customary to rotate the chairmanship and also the vice chairmanship of the council each year so that neither officer may succeed himself.

The governors of the western states insist that the recommendations of the council be both reasonable and feasible.

INTRODUCTION

roughout the West, almost all states are heavily dependent upon the ction of minerals and fuels for their basic economies. One mining state ves over 60 percent of its direct revenue from these sources. With the of rapid population increase in western states, the problem of providing olls for these new citizens becomes critical.

erdependence of western states is demonstrated by the fact that the ns of inland states make substantial purchases of supplies and manufac- articles from businesses in the coastal states with funds obtained largely mineral production.

whatever extent each of the states produces minerals and metals, such ction represents new wealth—wealth which is spent widely to satisfy nds of the producers for goods and services. When such production is ed or stopped the economic effect is felt both in the immediate area and as from which purchases are made.

e condition of domestic mining, with the possible exception of copper, s from poor to critical and its future is indeed uncertain. Since the ssion years, metal mining has struggled with conditions adverse to explo- for new mines and development of new reserves. War periods have d maximum production demands and in the intervals conditions have ally been unfavorable for recovery from the strain. Government mineral has consisted of plans and pleas for increased production by many ent departments during emergencies and of indifference to the needs of dustry once adequate supplies are again available.

imony and thorium mining have all but ceased; underground gold min- such is represented by but one major operation; fluorspar, lead and nining have been substantially curtailed and many other segments of dustry, including uranium, mercury, the strategic minerals, and silver, ncertainties related to governmental decisions on policy and legislation.

ses contributing to the present condition of the mining industry are ous and complex. A few of the most basic ones are enumerated below:

ncreased labor, supply, transportation, and utility costs without com- ensating increases in price.

overnment loans, grants, and floor price contracts granted to foreign roducers on the erroneous basis of a "have not" appraisal of domestic ineral productive potentialities.

3. Drastic reduction of the effectiveness of rates of duty on imp minerals and metals. Because of price increases and tariff cuts negot under the Trade Agreements Act, fixed duties have declined fro average of about 40 percent of the market price in 1939 to less 10 percent at present. Raw materials, through fixed duty rates because of the shortsighted desire to obtain them at the lowest pos price, irrespective of source, have suffered greater tariff cuts than other major domestic industry. Duties on most metals and mineral considerably below a level necessary to protect the American wor man and investor from similar materials produced abroad under c tions intolerable to the American working men and often prohibiti our free enterprise investments.

4. During the last 10 years the mineral industry of the world has sup not only the consumptive demand but also the tremendous amou metals and minerals which have been accumulated under the de stockpile program. Most of this metal has come from foreign so and most of the productive capacity so built up in foreign lan already amortized. When stockpiling ceases, which cannot now be m years away, there will be a capacity for production of most metals minerals in excess of the expected requirements of industry. When occurs the high-cost segment of the expanded world productive capa will be forced to close and the burden of closing will fall heavies operations within the United States.

5. Failure to gain needed relief from harm caused in negotiated t agreements under the escape clause, peril point, and national sec provisions of the Trade Agreements Act.

6. A tax structure unfavorable to investment of venture capital in the l range activities of mineral exploration, development, and research, re ing in an inaedquate testing of domestic mineral potentialities an lesser ultimate tax revenue than a more practical policy would produced.

7. Regarding the public domain, certain segments of government threatened the rights of location and patenting of mineral lands; have also caused substantial public domain withdrawals of question need in which withdrawn areas mineral locations are prohibited.

8. Adoption of short-range solutions to basic problems have served onl continue the liquidation of the industry rather than to give it new Between tax impact on profits and lack of a sound, long-term nati

> mineral policy no real incentive exists for substantial investment in exploration for and development of new mineral or metal deposits. This condition is particularly applicable to those minerals and metals which are sold as raw materials competitive with products of foreign mines.

Stockpiling is an example of a short-range solution. As soon as stockpiles isfy military requirements, both the industry and government are subject criticism if such stockpile purchases continue. Stockpiling without reason- le import controls fails to correct conditions creating surplus stocks and ves the domestic producer, when stockpiling terminates, facing the same sic problems that existed when stockpiling began.

Congress recognized the lack of justice in the unfair competition furnished excessive imports when it amended the Trade Agreements Act to add the cape clause, the peril point and the national security provisions. However, ose protective devices have failed even when the mining industry presented equate proof of damage.

Recently, the President of the United States and his Cabinet Committee on ineral Policy declared that a healthy domestic mining industry was vital the Nation's security and peacetime economy and, further, that the domes- mining industry should provide an "adequate mobilization base" for any ssible future emergency.

The State Department, however, would further reduce tariffs on metals d minerals, all raw materials in fact, to improve its bargaining position espective of the effect on the domestic economy or on the capacity of the lustry for continued production.

So long as these two conflicting policies continue, mining suffers in the cuum of inaction created. If the President's desires are to be attained they n only be realized *by assuring to the domestic mining industry their fair re of the domestic market. By whatever means that fair share is assured, an only be preserved by excluding from the domestic market any foreign plies in excess of need.*

t is historically true that when world metal shortages exist the United S tes falls far short of obtaining needed supplies, but when surpluses exist full "free world" supply floods our market, causing depressed prices and nestic mine closures.

Regardless of their views on the issue of import controls or import freedom, re are few who will dispute the claim that mining has been seriously med by the extent of import freedom established through trade agree- nts since the 1934 act was passed. The differences arise in the form of ef needed.

Those favoring free trade advocate subsidy type remedies; remedies w cl
are expensive to the taxpayer and lead to government interference n
controls.

Those favoring import controls ask basically for only sufficient protec oi
to insure continuity of enterprises whose costs of producing raw mate al
are consistent with the level of our domestic economy. Those costs inv v
consideration of comparative wages, taxes, supply cost, transportation to ır
ket, and average grade of the source material. Any plan whether it be sub d
in nature or tariff in nature must consider and provide for those compara v
factors to perpetuate the industry.

Tariff forms at present vary through ad valorem, fixed rate, distribu oi
of tariff receipts to domestic producers, and an excise tax on imports ap li
cable only when domestic price falls below a stipulated level. Tariffs oi
manufactured goods are usually on an ad valorem rate, while fixed rates ır
prevalent on raw materials, a condition which has served to effectively red c
the measure of protection as prices increased in the inflation of the pas 1
years. No one type of tariff may be practical for application "across h
board" to all segments of the mining industry, but in the following rec m
mendations tariff needs are presented and preferences stated by qual e
representatives of the numerous segments of the industry attending h
conference.

Another point of importance is the fact that the only way to encou g
the development of substitutes for strategic materials is to increase the os
of those strategic materials so that it would be to industry's advantag t
develop and market substitutes. There is certainly no incentive for indu r
to develop substitutes for materials like manganese and chrome, which ar
obtainable in the market place at the equivalent of 5 cents a pound and s
long as those and other similar materials are available in ample supply at t
prices, we can be assured that no substitutes will be developed. Almost n
conceivable substitute would cost more than the material it replaced an n
manufacturing industry will willingly use a high-priced substitute for a lw
priced material.

Recommendations are hereinafter presented on the numerous prob m
outlined above, for the earnest consideration of the western governors. h
recommendations made, in the carefully considered opinion of the deleg te
to the conference, form the framework of a national mineral policy on w c
can be established a healthy domestic mining industry, capable of provi n
an adequate mobilization base and serving its true function in our dom t
economy.

MINERAL ECONOMICS

RECOMMENDATIONS ON MINERAL COMMODITIES

old

e council calls attention to the following conditions in regard to gold:

) The absolute and arbitrary control exercised by the United States sury over the production, disposition, and holding of domestic gold is rect violation of the rights of personal liberty, personal security, and nal ownership of private property.

) The government has usurped the right of individuals to sell newly d gold to industry and to the arts, and has denied individuals the right wn, buy, or sell this commodity in a free market.

) The sale of gold from our federal gold reserve for other than monetary nnually exceeds the total domestic gold production and is dissipating the d States monetary reserves.

By making itself the sole buyer of newly mined gold in processed form y fixing its arbitrary and low price, the United States Government ses such hardships on the domestic gold producer that 95 percent of the ry gold mines have been forced to close operations.

e council recommends that:

Congress be urged to enact legislation to discontinue the sale of gov-
ent-owned gold from the monetary reserve to private industry and to e to the people of the United States the right freely to buy, possess, nd otherwise treat gold. Such legislation is now pending in the Congress, eferences to gold therein should be amended so as to not limit the re to newly mined gold.

(The respective state legislatures be requested to urge the Congress to rt such legislation.

ver

council recommends that:

(The existing policy, whereby newly mined domestic silver may be ed to the Treasury Department for coinage purposes, be continued.

(Senate Bill 1427, "A bill to repeal certain legislation relating to the ase of silver and for other purposes," be rejected by the Congress.

(As longer range objectives, the council further recommends that:

a. The sale of government-owned silver by the Treasury Departme t less than its coinage value of $1.2929 per troy ounce be prohibited a

b. The seigniorage retained by the Treasury Department be progress reduced in recognition of the steadily mounting cost of producing s

(4) The council highly commends the governors and the legislators o Western States for the vigorous support which they have given to the mining industry, and we respectfully call to their attention the fact that h continued support is urgently needed.

3. *Lead and Zinc*

The council recommends that:

(1) An excise tax of 2 cents per pound be established on imports of z and lead to take effect whenever the price of zinc falls below 14 cents E St. Louis, and the price of lead to 16 cents, New York.

(2) The present stockpiling of lead and zinc should be continued u such an excise tax is put into effect.

4. *Copper*

The council recommends that:

The present excise tax on imported copper be maintained.

5. *Molybdenum*

The council recommends that:

The national stockpile program on molybdenum concentrates be cont until maximum emergency defense requirements are met.

6. *Fluorspar*

The council recommends that:

The fluorspar industry be afforded tariff protection and/or restricti fluorspar imports sufficient to permit its survival.

7. *Uranium-Vanadium*

The council strongly urges that:

The Atomic Energy Commission make a prompt public declaration re ing the continuation and extension of its uranium purchase program. p the announcement of its proposed program the domestic industry at should be provided an opportunity to appraise and evaluate said prop program and to submit further recommendations before its final adop Meantime, so long as the government retains control of the purchase an of uranium, the council looks to the Atomic Energy Commission to ma an adequate purchase program and to prepare plans for an orderly tran e current monopolies to the period when industrial requirements inate.

council strongly urges that more access and mine-to-market roads be l and completed with all possible speed.

council favors the continued curtailment by the Atomic Energy Com- of its exploration drilling program and urges that funds hitherto d for that purpose be made available to the Defense Mineral Explora- lministration.

council further recommends that:

security program be re-examined in order that maximum information le available to the industry for effective future planning.

Atomic Energy Commission should arrange to facilitate and plan con- of studies of problems of the industry related to the marketing of n ores, in particular: (a) penalties now being imposed for high lime t; (b) the disposition of other metals produced in association with n including vanadium, copper, et cetera and (c) the feasibility of hing fixed uniform prices for uranium concentrates. These studies enlist the personnel and experience of the Atomic Energy Commis- ppropriate state and federal agencies as well as private research organi- and the producing industry.

council urges that:

ll future raw material purchase programs that the domestic uranium y be given paramount consideration.

e Earths and Thorium

council recommends that:

The Atomic Energy Commission should establish a price and buying le for thorium similar to that for uranium, since it has complete control h these fissionable materials.

A tariff be placed on foreign monazite, bastnasite, and rare earth com- s which is sufficiently high to permit domestic producers to survive. ff of 10 cents per pound on contained rare earths metals is suggested.

Until Nos. 1 and 2 above are effective the Federal Government should new contracts to purchase monazite and bastnasite concentrates in suffi- quantities and at a price which will maintain an adequate mobilization or the industry.

icksilver

council calls attention to the fact the market for mercury is assured S. A. purchases until December 31, 1957, but it has no knowledge of any definite demand which could assure the continuation of the domst industry much beyond that date.

The council recommends:

(1) The establishment of a tariff equivalent in protection and at the n percentage of the selling price as at the time the present tariff was establi (1922).

(2) If this is not possible, there should be established a plan of distribu the tariff paid by foreign producers to domestic producers in accordance i their production with the tariff adjusted from 25 cents per pound to 35 n per pound.

(3) In the absence of 1 or 2 above then the General Services Admini tion purchase program should be continued until the present appropriati expended.

10. Tungsten

The council recommends that:

(1) An adequate tariff be established to enable the domestic tungsten i ing industry to stand on its own feet and compete with the low-cost fo producers.

(2) If it is impossible to obtain such a tariff, then an adequate tari imported tungsten ore should be established, the proceeds of which mu distributed to the producers of domestic tungsten produced and sold wh the United States, in proportion to their production.

(3) A purchase program for a reasonable period be established provi for reduced government purchases at lower than current floor prices, s on the grade and impurities of the concentrates purchased, and with g ally reducing amounts and prices to enable complete withdrawal o United States Government from the program by the end of that pe

(4) Until 1 or 2 and 3 above are put into effect, the principles and pur as expressed in H. R. 6373 (84th Congress), be reaffirmed as desirable o tives to provide a continuing and prosperous tungsten mining indust order that an adequate mobilization base might be maintained.

The council suggests:

That the Department of Defense be advised that it is no longer nece to "design around" tungsten. It should be used wherever and whenver best suited to the defense problem in hand.

11. Chrome

The council recommends that:

In order to prevent the domestic chrome industry from being shut o in the fall of 1956 and in order that the industry might continue as a mo zation base for possible emergency, that:

(1) A tariff be established of 5 cents per pound on contained chromium etal in imported chromite ore;

(2) If it is impossible to obtain such a tariff, then a tariff equal to five-ghths cent per pound on contained chromium metal in imported chromite e should be established. The proceeds of this tariff must be distributed to producers of chromite produced and sold within the United States in oportion to their production. Then the chrome industry could continue o the foreseeable future as a strong, healthy industry, capable of expansion d able to act as a mobilization base in time of national emergency;

(3) Until such a long term program as outlined under 1 or 2 is adopted d put into effect, the General Services Administration purchase program uld be continued on its present basis.

Manganese

The council recommends that:

(1) A tariff be established of 5 cents per pound of contained manganese in ported foreign ores;

2) If the stipulation in paragraph 1 is impossible, then a tariff equivalent one-half cent per pound of contained manganese be imposed, the proceeds ng distributed to domestic producers on the basis of each domestic procer's unit production produced and sold;

3) The limitation of 10,000 tons on the carlot program be eliminated until provisions of either paragraph 1 or 2 are adopted;

4) If the recommendations in paragraphs 1 and 2 are impossible, then a gram similar to the present carlot program should be put into effect over ng term of years.

he council suggests that:

very effort be made to obtain a treatment plant at either the Deming, w Mexico, or the Wenden, Arizona, depot to beneficiate stockpile ores to ble grade.

Antimony

order to reactivate domestic antimony production the council recomds that:

l) Minimum tariff rates be established:

On antimony ore and concentrates at not less than 15 cents per pound of contained antimony; and

On antimony smelter products at not less than 30 cents per pound of contained antimony.

(2) If it is not possible to obtain such tariffs then a tariff of 6 cents e pound on contained antimony metal in imported antimony metal, ores o concentrates should be established. The proceeds of this tariff must be is tributed to the producers of primary antimony, produced and sold wi i the United States, in proportion to their production.

14. *Asbestos*

The council recommends that:

(1) Unused funds now earmarked for the purchase of No. 3 fibre be n d available to purchase additional No. 1 and No. 2 high grade fibre, ther making usable all of the funds allocated to the G. S. A. Globe wareho The purchase of No. 3 should be continued on the present ratio of three of No. 3 purchased to each ton of No. 1 or No. 2; (approximately $1,000 remains in the No. 3 fund to supply funds for the above change in program).

(2) Fibre of national stockpile quality now in the Globe warehouse transferred to the national stockpile and the Globe warehouse be cred accordingly;

(3) The life of the asbestos program be extended. This can be done making available to Arizona asbestos producers part of the funds alloc to the national stockpile and changing the present Globe warehouse prog as in No. 1 above;

(4) The inspection of fibre for transfer to the national stockpile be by G. S. A. classifiers now inspecting Globe warehouse fibre;

(5) Fibre of national stockpile quality and sold to the national stockpil checked in at the Globe warehouse and paid for as now being done thro San Francisco Office of G. S. A.;

(6) The present standards of quality be retained.

15. *Coal*

The council recommends that:

The governors give equal consideration to all of the available en resources—uranium, coal, oil, gas, oil shale and water—before deciding w is to be used as the source of generating power in any given area.

16. *Aggregates-Clay-Talc*

The council recommends that:

The congressional committees on interstate and foreign commerce be u to investigate the encroachment by the I. C. C. regulations on many min and mineral aggregate in intrastate commerce.

LANDS AND WATER

The council considers the objective of the General Mining Laws to be the covery and development of the mineral resources of the public domain private enterprise. To effect this objective the laws invite citizens to spect for minerals and upon discovery to locate valid mining claims. The ing laws also provide for protection of valid claims and the possessory hts thereunder prior to patent, and for transfer of legal title to private nership by patent. History has proven the soundness of this system, and council reaffirms its confidence in it.

The council holds that public lands are not the property of the Govern- nt of the United States or of any of its agencies but instead are lands held rust for the people of the United States, and are destined for their eventual under the principles of free enterprise. Vast areas of the West have in spect many present and future uses, but they are most likely to find best as a source of the national mineral wealth.

he continued inroads upon the use of this land which are made by federal hdrawal of the land from mineral entry or by acquisition by various agen- of the Federal Government, have long been adverse to the economy of West. Such inroads have been tremendously augmented in recent years military acquisition of huge areas in the western states. This has served curtail seriously the productivity of private enterprise within the State, to reduce state and federal income, as well as the supply of materials for defense of the Country. Under present laws, no federal land state has the ver effectively to resist such inroads.

or those cogent reasons the council recommends that:

As to federal land withdrawals:

. The western governors urge an immediate congressional investigation of federal lands now withdrawn from mineral entry and other beneficial uses, whether withdrawn for military or other purposes, and of western lands otherwise acquired by the various agencies of the Federal Government; that among other things such investigation determine the necessity for and the authenticity of the withdrawal, whether the land is still serving the purpose for which it was withdrawn or acquired and whether portions of it or the whole of it may be returned to the public domain or to private owners (with priority right for repurchase given to original owners); and that such investigation determine whether the various agencies and military units cannot combine their activities as to the use of such lands rather than making separate use thereof, in order to give such land the highest possible usefulness.

b. Congress be urged by the governors to explore the possibility of fede legislation requiring the cooperation and approval of any state for a federal withdrawal or acquisition within its boundaries.

c. The western governors request Congress to enact legislation to prov that in all further federal land withdrawals, either for military use otherwise:
   (1) Public hearings be held on the proposed withdrawals.
   (2) These hearings be held in at least one community within or n the area proposed for withdrawal.
   (3) Notice of these hearings be published in the Federal Register in a newspaper having maximum circulation in affected areas, least 90 days in advance of the hearings.
   (4) These hearings shall seek to determine the relative beneficial of the land involved, and whether excessive acreages are be proposed for withdrawal.

2. As to the Oil and Gas Leasing Act:

The western governors oppose any further amendment of the Oil Gas Leasing Act, approved February 25, 1920 (41 Stat. 437, 30 U. S. C. 181, et seq.), or any other legislative proposals which would add further classes of lessees or any minerals or mineral deposits to those n named in said act.

3. As to Mineral Leasing Act:

The western governors urge the Department of Interior to reappr the maximum acreage limitations presently existing on the leasing of f eral mineral lands withdrawn from location and increase the acreage meet the requirements of modern mining and refining needs. Illustrat of such need is phosphate.

It is the considered opinion of the council that no further restrict should be placed upon the noncompetitive lease rules and regulations that such regulations should be so administered as to encourage the inv ment of venture capital.

4. As to restrictive federal legislation:

a. The western governors oppose any and all legislation in the Cong that promotes further control and withdrawal of federal lands from public domain.

b. The governors urge the Congress of the United States to return to first principles laid down by our founding fathers, that the federal la of the United States are for the benefit of the citizens and should sold and disposed of to the citizens as rapidly as is practically possi so that those lands may be made the subject of private ownership our citizenry and the subject of taxation for the support of local and state governments.

The western governors advocate the annulment of the rules and regulations promulgated by the many departments of government withdrawing and otherwise prohibiting possession of public lands by the citizens of this Nation, so that the citizens may again be free to take up the land under the original laws relating to mining or agricultural classification and carry that land through to patent without interference by a multitude of governmental agencies.

to geophysical exploration:

The governors urge Congress to give prompt consideration of construct changes in the discovery provisions of the General Mining Laws so a o afford a reasonable period of protection to those who in good faith s k a mineral discovery where the object of exploration is a deep or h den deposit and discovery can only be made following prolonged use expensive equipment and modern scientific methods of prospecting.

to "in lieu" lands:

he western governors recommend to Congress a thorough study of need for legislation serving to permit the public land states to make lieu" selection from mineral lands, for the mineral lands lost to the e because of the pre-emption of numbered school sections before the e's right to such sections was determined by survey.

to state mining laws:

he western governors investigate the desirability of making more uni- n the laws of the various states governing location and annual assess- nt work, and other mineral land matters within their jurisdiction.

TAXES

council holds that the continuance of a healthy and prosperous mining y and the contributions it can and should make to the public revenue, ployment, to national security and to the general welfare, depends upon uing production from now operating mines and the continuing dis- and development of new deposits. Essential to this is the hope for commensurate with the difficulties, the effort and the risks of losses ed. The inherent risks in mining cannot be avoided, and taxes should imposed in nature or amounts as will kill incentives for incurring these nd will result in loss of government revenues and harm to the domestic ny.

The council recommends:

1. As to depletion:
   a. Full and adequate allowance for percentage as well as cost deple should be provided for all minerals on a fair and equitable basis, not favorable than present rates. We particularly note the necessity of s allowances in the development of so-called oil shales in the wes states.
   b. Depletion should be recognized as an allowance to stockholder determining the taxability of dividends they receive as well as b allowed to the corporation in determining its taxable income.
2. As to exploration costs:

   Costs of exploration, as well as development, should be allowed deduction without the limitations imposed by present law.
3. As to depreciation:

   The provisions for more reasonable depreciation contained in pre law should be retained without fundamental changes. No amount sh be considered as recovered by depreciation deductions which has not ef tively reduced the taxpayer's income subject to tax.
4. As to operating loss:

   The more equitable allowance of net operating losses provided by p ent law should be maintained.
5. As to research expenditures:

   The allowance under present law as a deduction of expenditure research and experimentation should be preserved.
6. As to double taxation of corporate earnings:

   The small step recently taken to minimize double taxation of corpo earnings should be enlarged.
7. As to new mines:

   New mines should be exempted from income taxes for three years commercial production begins.
8. As to capital gains:

   A further reduction of the rate on net long-term capital gains woul economically beneficial to the mining industry and, on the basis of experience, would increase net revenue collected.
9. As to severance taxes:

   In state taxation, no particular tax nor the combined federal, state local taxes should be such as to discourage the exploration and dev ment or production of minerals. Severance taxes or taxes based o measured by gross output should be avoided.

RESEARCH

'he council recommends to the governors serious consideration of the owing discussed facts and conditions affecting industry research.

.esearch is the very foundation upon which growth of the mineral induss must depend. For the future health of the mineral industries and of the re national economy, there should be vigorous research activity supported :ctly by private industry as well as by state and federal agencies, each :king in the sphere for which it is best fitted; and

Vith respect to privately supported industrial research, economic factors ıld be such as to give maximum encouragement to industrial expenditures research. This viewpoint is embodied in a recommendation on taxes, 'ed in by the research committee; and

ince many research projects involve financial commitments over a long od of years, the lack of a clearly stated national mineral policy, has ted industry's willingness to undertake such long-term projects. It follows the adoption of such a national policy, to which all these recommendas are devoted, will do much to encourage industrial research.

/ith respect to state and federal research, the council recommends the ›wing:

Establish at federal level, and at state level where desirable, permanent minerals research advisory boards. These boards should consider and recommend initiation of research programs which, in their opinion, are particularly needed.

Encourage federal and state mineral research programs at appropriate state agencies, universities and nonprofit research foundations.

Expand or establish in each of the mining states a clearing house or library of pertinent technical information and records dealing with all phases of the mineral industries.

The mineral industries of many of the western states, particularly the small mine operators, need some form of central clearinghouse for pertinent technical information which would be readily available in suitable form.

Continue support of existing long range research in federal and state agencies.

Geologic and topographic mapping should be accelerated as an essential part of this long range program.

PUBLIC INFORMATION

When and if the governors approve the recommendations the cou recommends that the western governors authorize the Western Govern Mining Advisory Council to undertake the following public relations act ties to attain the widest possible public understanding of the policies adop by them as a result of the Western Governors Mineral Policies Conferen

1. Distribute to all related and interested organizations the recommen tions on national mineral policy affecting the mining industry as adop by the governors as a result of this conference.
2. Distribute basic information related to the recommendations necess to promote the broadest possible public reception and understandi
3. Continue to distribute such additional information as should sub quently develop relating to those recommendations.
4. Obtain the full cooperation of all organizations and agencies, private a public, whose interests are related directly or indirectly to the min industry.

POSSIBLE SOLUTIONS CONSIDERED IN DEVELOPING RECOMMENDATIONS FOR THE VARIOUS MINERAL COMMODITIES

Presented by S. H. Williston, Chairman, Western Governors
Mining Advisory Council—1954, 1955

The Western Governors Mining Advisory Council and the Western G ernors Mineral Policies Conference made a special effort to explore all p sible proposed cures which might assure a healthy mining industry in Western States so that it might serve as a mobilization base in times emergency.

These studies included tariffs, excise tax on imports, quotas, "the paym of tariff receipts to domestic producers of the same materials in accorda with their production," across the board subsidies, premium price plans used during World War II, floor prices and stockpiling.

The following brief statements give the advantages and disadvantages each proposed method, together with the conclusions of the council and conference:

Problem. The principal uncertainty in western mining is the direct re of operating costs rising faster than the sales price of the correspond minerals. Labor costs since 1939 are now three to four times what they w etal prices on the other hand, except for copper, mercury and lead, are less an three times their 1939 base. The costs of mining supplies have similarly en faster than the sales price of the metals or minerals.

ssible Corrective Measures

Tariffs. In most cases, tariff rates on metals are set in cents per pound. riff cuts on metals under the Reciprocal Trade Act and as a result of lation have reduced the tariffs from a 1939 level approximating 40 percent valorem to present rates which almost without exception are less than percent ad valorem.[1]

Since 1939, in place of being an exporting nation in metals, we have de- ned to a position of where we import more than half of our requirements cept for tungsten and molybdenum. If the present average tariff rates even sely approached the average tariff rates in 1939, the mineral industries of West would in most cases be in a healthy condition and well able to act strong mobilization base for any future emergencies. Both the Governors visory Council and the Governors Policy Conference felt that this method preserving the industry would be the one sure method. Such a procedure uld also increase income to the National Treasury and assist in balancing budget.

Iowever, the conference and the council also recognize the fact that both Republican and Democratic Parties have adopted a policy of reduction ner than increase in tariffs and the State Department has made commit- nts which may make adequate tariffs most difficult to attain. In addition, ough the cost of metals makes up but a very small portion of the cost of nufactured goods,[2] eastern purchasers would probably oppose such tariff eases.

xcise Taxes on Imported Metals. Utilization of excise tax on imported erals (as is now effective on copper) differs but little from a tariff. The cipal difference is that any excise tax on imported materials would only ffective so long as the price of the material was below some fixed figure would be removed whenever the price of the metal or mineral was above figure. The conference and the council both felt that this would be lly effective as a tariff in preserving a healthy western mining industry mobilization base for possible emergency.

uotas. The setting of quotas on mineral and metal imports would pre- e for the domestic mining industry their fair proportion of the domestic

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erate tariffs do not decrease supply. To the extent that they increase domestic production they crease supply.

value of the ores and concentrates needed to make the metals used in an average automobile is s than $100.

market and to that extent it would be similar in effect to either tariffs r excise tax on imports. It would, however, require the estimation in advane of probable United States requirements and the distribution of the impt quotas to the various other producing nations throughout the world. A sligt error in the setting of the original quotas could make the operation of te system ineffective and the difficulty of apportioning those quotas to othr nations would be exceedingly complex and subject to heavy political ad international pressures. The conference and the council greatly doubted tht any quota system could be made workable and felt that it was impossible o recommend such a solution to the western governors.

"*Payment of Tariff Receipts on Each Metal or Mineral to Domestic Prducers of the Same Metal or Mineral in Accordance With Their Domesc Production and Sales.*" This possible solution is less well known than te other methods considered by the conference and the council. If we were o take an imaginary metal as an example of the method of operation, then te results would be somewhat as follows: If in considering this imaginary mel we assume that it has a tariff fixed in cents per pound at a level approximatey equivalent to 10 percent ad valorem, and if we assume that domestic prodution is equal in amount to tariff imports, then the domestic producer of ts metal would have two factors increasing his price above the world pri. The first of these would be the amount of the duty or 10 percent. The secod would be the receipt of the tariff paid by the foreign producer or anothr 10 percent. Thus the domestic producer would receive for his metal 20 pcent above the world price. If we assume another metal where domesc production is one-third imports but with the tariff rate set exactly as in te case of the first imaginary metal at a fixed number of cents per pound equalent to 10 percent ad valorem, then this second producer would have te same two factors but in different proportion. The first factor would be 0 percent above the world price. The second factor would be three times s much. The total would be the equivalent of a 40 percent ad valorem du.

If imports increased at the expense of domestic production, allocated tarf receipts would increase. If domestic production increased, allocation of tarf receipts would become less and less important. In general, the proposal isa compromise. It increases the tariff protection to domestic producers withot increasing the tariff rates. Thus it does not conflict with the policies of te Democratic or Republican Parties, it does not interfere appreciably with te negotiations of our State Department with foreign countries, nor does it drv on the taxpayer of the United States to support a domestic mining industy in a condition where it could remain healthy and serve as a mobilization be for times of emergency. The conference and the council felt that this co e might be workable in the event that tariffs or excise taxes on imports mpossible of attainment. This compromise could not correct the situa- any metal where we had an exportable surplus as in the case of denum and temporarily in the case of tungsten. Nor could it be effec- regards the monetary metals, silver or gold, or the fissionable metals the United States Government maintains a monopoly as in thorium ranium. In most other cases it might be made applicable by minor s in the tariff rates not much different from the 10 percent ad valorem

oss the Board Subsidies. Across the board subsidies propose a payment ixed number of cents per pound to all newly mined metal produced the United States varying in amount from metal to metal but uniform ount for any one metal. Such a program might have the desired result th the conference and the council felt that this method would result government's directing all phases of metal mining within this Country sult of their ability to arbitrarily change the market price. They felt would have all of the disadvantages of the present farm subsidy pro- combined with the further uncertainties of annual congressional appro- ns and that no competent mining company could afford to make com- nts for exploration or development under such an uncertain program. onference and the council felt not only could they not recommend it to vernors, but that they should oppose it if any such recommendation national policy was recommended by others.

mium Price Plan. The premium price plan as utilized in the closing of World War II was also considered. This involves differential prices o the producer of each metal and of the different producers of the same . It was the consensus of the conference and the council that such a must of necessity end up on a basis of cost-plus contracts. This would y incentive and destroy efficiency. A healthy industry could not survive ithout a healthy industry no sound mobilization base is possible. The rence and the council therefore opposed this suggested method as being ctical and impossible.

or Prices. The establishment of floor prices for metals and minerals l closely parallel the establishment of floor prices for farm products. floor prices were set too low, they would be ineffective. If the floor were set too high, they would produce unmarketable surpluses. Since oor prices would be set by political action, and the appropriations would ject to congressional approval, then both the conference and the council felt that such a program could only be justified as a stop-gap continua of present floor prices until a long term national policy could be adop

Stockpiling. The national stockpile for defense is now approaching c pletion. The purchase of materials from domestic sources whenever avail might well be of considerable help in maintaining a healthy mineral indu until such time as a national policy could be adopted, but both the confer and the council realized that such defense stockpile purchasing could no on after reasonable objectives had been reached. As a result, they could recommend such a program as stop-gap legislation until a long term nati policy could be adopted.

No Action. If none of the mentioned plans is adopted and if no plan is devised, the mining industry sees a future with steadily declin domestic production and steadily increasing imports. This will cause incr ing difficulties in the economies of the western states. There will be healthy domestic mining industry and there will be no broad mobiliza base. In the event of an all-out war, there will be no supplies from abr that would even approach in quantity our military needs, let alone civilian requirements.

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APPENDIX

REPORT OF THE COMMITTEE ON RESEARCH

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TABLE OF CONTENTS

Page
I Summary and Recommendations 638
II The Role of Research in the Mineral Industries 638
III Agencies to Support Mineral Research 641
IV Agencies to Conduct Mineral Research 643
V Recommendations 647
VI Appendix (A letter to the Tax Comm.) 653
VII Acknowledgments and References 655

I. SUMMARY AND RECOMMENDATIONS

Research is the very foundation upon which future growth of the min industries must depend. However, because of certain economic factors so segments of the industry have lagged behind in their research developme This is particularly true in the field of mineral exploration. To correct t situation and—by expanding research activity—to insure a continued heal growth of the industry, we recommend that the following steps be tak

1. Establish federal and state sponsored mineral research programs at va ous appropriate universities and nonprofit research foundations.
2. Grant a certain portion of state tax revenues and obtain federal funds support such research programs.
3. Continue support of basic research in federal agencies.
4. Establish, in each of the mining states, a clearing house or library pertinent technical information dealing with all phases of the mine industries.
5. Establish at both state and federal levels a permanent minerals resea advisory board.

These summarize the more urgent of the committee's recommendatio They are discussed and other important recommendations are given in P IV of this report.

II. THE ROLE OF RESEARCH IN THE MINERAL INDUSTRIES

To anyone familiar with the history of the American mining industry, will scarcely be necessary to establish the importance of research—and continually expanding research—if the industry is to continue to pros for itself, and in so doing, provide for the prosperity of the Nation. It i truism that agriculture and mineral production are *the* basic industries; th far more than any other industries, *create* new wealth; they more than an- thing else provide the *material basis* for prosperity.

According to the best obtainable estimates, for the latest year for whi data are available (1952), research expenditures * in the United States these two important fields were as follows:

	Agriculture	*Mining*
Federal	$56,000,000	$33,000,000
States	56,000,000	1,500,000
Industry	50,000,000	6,000,000

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* It would be interesting to present research expenditure as a percentage of value of the total prod but with currently available data this appears impossible. What is an agricultural product—is it grain of wheat as harvested in the field, or the loaf of bread that comes wrapped and sliced to y table? And what is a mineral product—is it the complex ore that comes out of the ground, or refined metal ingot that goes to the fabricator, or the aluminum frying pan in the hardware st

re the question might well be asked, "Is not research just as important e mineral industries as it is to agriculture?" Most thoughtful persons d answer, "yes"; and there are many who would go on to say "Research *ch more important* to the mineral industries because they, unlike agricul- deal with a wasting asset."

r those who are less familiar with the mineral industry, but who as c spirited citizens are concerned with maintaining a healthy economy, ps just one illustration will suffice to indicate the importance of research minerals industry. And this particular illustration has been chosen, not se it might seem an exaggerated case, but because it illustrates so well nportance of pure research—even "long-haired" and "academic" research industry.

e "uranium boom" which has been gathering impetus, at first slowly hen more and more rapidly, ever since the end of hostilities in 1945, ly described as "the greatest mining boom in history." The California e Alaska gold-rushes pale into insignificance beside it, as do such touted oms as followed, say, the Spindletop discovery on the Gulf Coast, and similar oil booms. Because of the nature of the uranium boom, as well ause of AEC restrictions, etc., it is impossible to obtain valid figures on rrent total investment in the uranium industry, on the amounts spent oloration and research, or on numbers of individuals engaged in the ry. Suffice that these figures would dwarf any similar 10-year minerals opment that the world has ever seen.

ere did it all start? *In research.* In the laboratory of Henri Becquerel, ssor of Physics in the Natural History Museum in Paris, more than 50 ago. It was Becquerel who first discovered radioactivity—a discovery d directly to the isolation of radium from pitchblende by the Curies, is in turn to nuclear fission and our present "Atomic Age." Certainly , whether legislator or scientist, could at that time have predicted the hing results which would follow, a half century later, from these gly abstruse discoveries. To be sure, if Becquerel and the Curies had scovered these phenomena, others—in the course of time—probably have. The important point is that engineering and applied science first pure research and basic discoveries, for without these primary pments, there can be no secondary developments—no useful appli-

re is another important lesson to be learned from the history of this development. After the beginning made by Becquerel and the others or basic research, progress toward practical use *and* greater scientific tanding of the atom was sure but nonetheless slow until the supreme effort of the Manhattan Project. With the "heat on" in recognition

of the need, teams of scientists, in well-equipped public laboratories devo
specifically to the declared purpose, accomplished 30 years of “pure” resea
in four years of directed research. We now have well-qualified opinions fr
all directions that urgency is a keynote in at least some aspects of our do
tic mineral reserves picture. In those cases recognized as critical, would
a similar concerted attack on the problems of mineral discovery and explo
tion produce great public dividends?

We need not belabor the point: research, both pure and applied, disp
and concentrated, is vital to the mineral industries. But although the conc
sion scarcely admits of argument, it does immediately raise a host of q
tions: how much research is needed; who should do it; who should pay fo
who determines what needs doing, and when and where? Properly to pla
research program takes time and long-range thinking. In the short per
since its organization, your Committee on Research has not had the necess
time itself to develop broad and thoroughly considered recommendati
Thus we have depended to some degree on reviewing and selecting p
posals made by other groups which have had opportunity thoroughly
review the desirability of certain programs in this broad field. Sugges
recommendations are presented in this report for supporting and carry
out mineral research activities. The committee will warmly welcome dis
sion at Sacramento of all the points raised, to the end that we can have
best possible guidance in framing, at the post-conference sessions, the
recommendations to the governors.

Before discussing specific problems, it would be well to define, as preci
as we can, some of the terms that will constantly recur.

> *Pure Research* or *Basic Research.* Some would differentiate t
> terms, but for this discussion they can and will be used almost syno
> mously. These are the kinds of research in which there is no immed
> practical objective: such research may involve a very broad object
> such as a study of “structure of glasses” or “diffusion in metals syste
> or it may involve a systematic study of a more specific objective, s
> as “solubility of quartz in water” or “solid diffusion in the sys
> Cu-Zn.”
>
> *Applied Research.* Here there is a definite practical objective,
> applied research for the mineral industries may appropriately be pla
> in one of three categories:
>
> 1. Exploratory phases,
> 2. Fundamental phases,
> 3. Engineering and pilot plant phases.

ls of Mineral Research

Exploration. Investigation of methods and equipment for the discovery ıineral bodies and for delineation of extensions and boundaries of known ːral bodies. Field includes refinement of theories of genesis and modes ccurrence of mineral concentrations; the geological, geochemical, paleongical, biological, geophysical, geophoto, etc., methods of exploring; and development of and field evaluation of equipment for such explorations. er this category are included exploratory drilling and logging of the holes.

Process Research. Investigation of methods of commercial production inerals and mineral products. Field includes theories of ore mining, millsmelting, refining and product formulations; and development and design quipment to carry out such processes. Process research is a large field of avor and may be broken down into subfields as follows:

Mining processes,
Concentration processes,
Refining processes (manufacturing).

Product Research. Investigation of new compositions and formulations ted at new products or improvement in old products. Investigation of uses for existing products.

III. AGENCIES TO SUPPORT MINERAL RESEARCH

ie two categories of research are so fundamentally different in their omic application as to make it self-evident that their principal sources nancial support should necessarily be very different. It is generally true among the private corporations only the very largest can carry out sive programs of pure or basic research and that by economic necessity rivate corporations must devote the great bulk of their research funds e applied field. In spite of this fact, it is still the accomplishments and veries in the pure and basic fields that produce the most revolutionary lynamic effects upon our modern civilization. These are the advances upon which a nation or a civilization can capitalize, but upon which ften difficult for a single industry or corporate member to gain economic itages commensurate with the research investment. In fact, from an omic standpoint, it is unfortunately often advisable for established induso make every effort to stifle advancement in competitive new industries.

e proper support and financing of all the phases of research can justi- require the participation of both private and governmental agencies. effect of progress in mineral research upon both the national economy

and international factors of defense and trade certainly justifies federal s
port of research projects.

State support of research can be more closely narrowed down to spe
phases of economic benefit to the particular states involved. A fixed per
of taxes collected from the wealth producing mineral industries within
State could well be directed toward the support of mineral research. S
support could produce a “breeder reactor” that would generate new t
which, in a relatively few years of well-planned research, would far m
than offset the expenditures.

Care must be taken that governmental agencies do not finance rese
that can and would be best handled under private projects. Every ef
should also be made to allow private participation by contribution of in
mation and funds to research organizations. As a matter of fact, if our do
tic mining industry were in a completely healthy condition and could s
reasonable distance into the future, the various mining companies, wit
little bit of encouragement, undoubtedly could and would carry on exten
research programs. It is unfortunate that, with the exception of copper, f
if any, of our domestic metal industries can plow significant amounts
research for future years. Thus, while everything possible should be d
to encourage mining industry research by mining companies, it seem i
capable that if research is to be done in these raw material industries, t
the Federal Government and the state governments are going to be ca
upon to supply most of the financial support. Nevertheless, and in gen
the field of applied research should whenever possible remain more wi
the realm of private sponsorship, while the broader phases of pure and b
research with their more indefinite economic objectives would provide
field of greatest need for governmental support.

One outstanding exception to this policy would be in the developmen
exploration methods for the mining industry. Advancement of explora
techniques has fallen far behind the developments in other industries
certain economic factors are at work which indicate that this situation c
continue to the detriment of our natural resource position. New techni
for geophysical exploration of mineral deposits, particularly metallic,
badly needed. However, the highly complex nature of the structural co
tions under which ore deposits occur makes their detection very diffic
and the required geophysical techniques more varied and complex than th
that have proved so successful in petroleum exploration. Information on
exploration procedures is jealously guarded by the larger mining compa
and each such organization goes its own separate way with very little sha
of the technical information so essential to a successful research effort. S

ing companies are completely unable to justify the maintenance of any loration research program and often make no effort to conduct any loration at all.

o provide a program for developing new methods of mineral exploration to make that information available to all mining organizations, will uestionably require government sponsorship.

the field of research every effort should be made to encourage private viduals and organizations to redouble their efforts and to release as much he information as they can possibly justify.

articularly in the exploration field it should be an important function of Departments of Mines and Geology of each state to maintain a depository ary covering all available information gathered from public or released n private files. All information on mining districts such as maps, reports ast shipments, geologic information, etc., should be carefully filed and le available, along with progress reports on mineral research projects. One ntial factor in all governmental research projects, both federal and state, ld be the rapid dissemination of information. Up-to-date progress reports ld be available at all times in order to speed up the transfer of information channels for commercial application.

IV. AGENCIES TO CONDUCT MINERAL RESEARCH

eral Agencies

ince the close of World War II the Federal Government has shown its gnition of the ever-increasing importance of basic research as the foundaof the technology vital to our national welfare and security by establishthree new research agencies:

1. *The Office of Naval Research* (Public Law 588, signed by President Truman, Aug. 1, 1946)

"* * * To establish an Office of Naval Research in the Department of the Navy; to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security; to provide within the Department of the Navy a single office, which, by contract or otherwise, shall be able to obtain, coordinate, and make available to all bureaus and activities of the Department of the Navy, world-wide scientific information and the necessary services for conducting specialized and imaginative research; to establish a Naval Research Advisory Committee consisting of persons pre-eminent in the fields of science and research, to consult with and advise the chief of such office in matters pertaining to research."

2. *The State Department Scientific Office*

"To extablish scientific staffs at certain selected United States dip- matic missions abroad."

3. *The National Science Foundation* (N. S. F. Act of 1950)

"* * * to promote the progress of science; to advance the natio health, prosperity and welfare; to secure the national defense; and other purposes."

These organizations, like the various other federal agencies of a scient or technical nature, are intended primarily to deal with problems of wor- wide or nation-wide scope and importance. However, apart from these ty of problems there are countless other problems in connection with ev branch of our economy waiting to be solved. Many of these are of a regio or local character peculiar to the individual localities involved. These m rightfully be the concern of state and local authorities as opposed to fede concern with problems of definitely national importance and scope.

Some past experiences with laboratory research organizations operated rectly by the federal or state governments have raised a question as to efficiency of this approach to research productivity. Granted that there h been some unfortunate examples, there have also been some notably success research laboratories and research bureaus at both state and federal level. T factors that determine success or failure are as various as the factors t govern the infinite variability of individual scientists, administrators, and p ticians. One most important factor, to which public agencies are notably ser tive, is *time*. In all research, no matter of what kind, or at what level, th is need for public, private, and political appreciation of the time fact Mineral industries research, like mineral production itself, cannot just turned on and off, like water from a spigot, whenever a local thirst devel or is temporarily satiated. Modern research calls for long-range planning a long-range programs. Good research men cannot be obtained for a laborato wherein funds are subject to wide fluctuation with each biennium or w each change of political administration, and it is wasteful to equip a laborato with modern instruments if they are not going to be fully utilized over t foreseeable life of the instrument.

Such agencies as the U. S. Geological Survey and the U. S. Bureau Mines have over the long run abundantly justified the funds that have be expended. The share of funds available to these agencies which can in m years be directed to basic research on a long-term basis has been too litt It would therefore be wise to increase the appropriations for basic resear either by increasing the general appropriation or by curtailing the amount

vice work" (usually applied research) that is demanded of these agencies
rganizations, political blocs, and individual "taxpayers."

ernment-sponsored Research

uasi-government or quasi-private organizations have been set up, wholly
part with federal funds, and by virtue of being at least one step removed
the season-by-season fluctuations in political influence, have achieved
iderable success. The National Science Foundation is one such example.
ther instances sponsorship of research, by funds from a specific federal
cy, within university or university-controlled nonprofit laboratories can
r a very considerable potential for gaining the economic advantage of
lready established organization possessing the finest resources of trained
continuing personnel. Such sponsored research programs also provide a
le field for practical training of graduate students and greatly increase
ability of universities to provide on-the-job types of training. The Los
nos Project (AEC sponsored) of the University of California and the
Propulsion Laboratory (Army Ordnance sponsored) of the California
tute of Technology are excellent examples.

Agencies

state-supported minerals research, it is vital that the program should
all who are interested in the mineral resources of the state, just as state
rch in agriculture should serve all agriculture interests. In addition,
efore, to basic research, the state programs can well emphasize at least
broader aspects of applied research. But in those states most concerned
he future of their mineral economy, basic research should be vigorously
ied forward. (In many instances it may be desirable to integrate with
research under federal sponsorship—the various federal-state cooperative
ogical mapping programs are good examples of this.) And, as in the case
ederal funds for mineral industries research, the several states may often
it advantageous to sponsor a laboratory or a research project in some
ersity or other research organization within the state.

ersity and Other Research Centers

niversities have been the traditional home of pure research, and every
uragement should be given to them to continue to enlarge these pro-
s. Mention has been made, above, of some of the advantages of allocat-
ederal and state funds to sponsoring university research laboratories and
rams. Research programs conducted by universities could also benefit
private grants made to the university by private individuals or corpora-
. Grants could be made directly to the university for equipment, build-

ings, etc., without necessarily running the risk of undue influence on direction or objectives of the research being conducted.

It deserves also to be pointed out that research organizations, of vary degrees of "nonprofit" type, have contributed notably to minerals indus research, and can be expected—with increased support—to make increas contributions. As one example, there is the Geophysical Laboratory of Carnegie Institute of Washington, a privately endowed organization, wh throughout its nearly 50 years of existence has devoted itself almost exc sively to pure research and in so doing has become one of the forem research agencies in the world, and has contributed immeasurably not o to peace-time development, but to our war efforts. As a rather different ex ple, there is the Battelle Institute, dependent almost entirely on indust support, and which has of necessity had to devote the major part of its eff to applied research. There is a place for both types of organization, just there is a place for both types of research.

Industrial Organizations

The industrial organizations within the minerals industries that cond research are so diversified, and the scale of research operations is so var that general comment is difficult to make. Furthermore, this committe naturally more concerned with public research than private.

One generalization safely can be made: Almost all industrial researc applied research, and in order that applied research may be successful needs basic data and basic research upon which to feed. Hence, progr of public financed basic research need the strong support of private indust

One further point concerning industrial research deserves emphasis. Th are those who fear that, if even moderate public funds are made available research, it will remove the incentive for private research. There are at le two good reasons why this will not be so. First, there is the naturally in pendent spirit of private enterprise, which our democratic society contin and should continue, to foster. The company which needs an answer t particular problem in exploration, production, or processing in the min industries will continue to be well advised to seek its own particular soluti or to engage the services of private consultants or foundations. Second, th is the fact that if, by and large, the public agencies concern themselves w pure research and only the broader aspects of applied research, then no competition exists with the domain of private industry, which economic must be primarily concerned with the more specific phases of applied resea

V. RECOMMENDATIONS

presenting below, some recommendations, the committee wishes to make ar that these represent no more than a sampling of the many that might vedly be included. It is our feeling that it is properly the business of cipants in the forthcoming Governors Conference at Sacramento to sug- make and shape the specific recommendations that will be forwarded e governors. Only by encouraging broad and thorough discussion can ventual recommendations be assured of public support.

e committee's function, therefore, is to provide—as we hope to have in the preceding pages—a background for discussion, and enough "sam- ecommendations," in the paragraphs which follow, to generate more and to develop more and better recommendations. Admittedly, we have ded, below, one or two recommendations on which the committee itself necessarily unanimously agreed—just because they are sure to arouse n-while discussion.

e recommend the establishment of federal and state sponsored mineral earch programs at appropriate universities and nonprofit research foun- tions.

many phases of research it has been demonstrated that the largest n, per research dollar expended, is to be obtained from research con- d in university laboratories and in the laboratories of nonprofit research lations. After all, in research, the man counts for far more than the ine, or the equipment, or the laboratory. Without able men, the most sively equipped laboratory will be completely sterile in research pro- ity; whereas a good man can often accomplish much with only limited ies. University laboratories and research foundations traditionally have ted, and should continue to attract and hold, the ablest men in basic ch. Assurance of added funds to such organizations provides assurance hey can maintain and augment the conditions for maximum research plishment.

h respect to state funds, it should be the responsibility of the state ls research advisory boards (see recommendation No. 5) to determine oratory best suited for undertaking any specific program, and to rec- d an appropriate allocation of funds. With respect to federal funds, esponsibilities should be either in a national minerals research advisory or in an appropriate committee of the National Science Foundation.

recommend that a certain portion of state tax revenues and of federal evenues be granted for the support of such programs.

rch that will ultimately benefit the public is properly supported by funds. This, then, becomes a problem in taxation; tax rates and tax-revenue allocations are both involved. This problem we have thought to refer to our colleagues on the tax committee (see the appendix to report).

3. *We recommend continued support of basic research in the federal agen*

Although most thoughtful people realize the importance of basic resea and realize the need for long-term programs, yet legislators and bu makers who are under constant pressure to cut taxes and to reduce expe ture, invariably find that projects on basic research are the ones that easiest to pare down or eliminate.

Can we provide any safeguards? Should we recommend that a cer percentage of taxes on the mineral producing industries be earmarked basic research in the mineral industries? Can we recommend a law estab ing basic research as the last thing that may be pared from a budget (ra than the first)? Again, we call attention to the appendix to this report.

4. *We recommend that there be established in each of the mining stat clearinghouse or library of pertinent technical information dealing wit phases of the mineral industries.*

This is needed, at state level, and is needed in almost every state. A g deal of research has been done in the past on various phases of the min industry, but the results, if published, are often hidden in obscure or hig technical publications not generally seen by the average mine operator. possible availability of information pertinent to his individual proble seldom known to him, but even if the existence of information is suspe it may be difficult to obtain. Also, without adequate technical or scien background, the small operator may find such information difficult to in pret or to apply under his conditions and therefore of little value in it

In short, the mineral industry of most of the Western States needs s form of central clearinghouse for pertinent technical information concer all branches of the mineral industry which would be readily availab suitable form to everyone, particularly the small operator, without ha to establish a "need to know" as in the case of certain federal informa agencies dealing with national defense.

In some of our states such information centers are operating as a func of the State Geological Survey, the State Bureau of Mines, or the S Department of Conservation and Natural Resources, as the case may In almost all instances these functions could very desirably be expan Mechanisms for accomplishing this will vary, according to local condit from state to state. In some petroleum-producing states laws have alr been passed requiring that a split from every core sample taken in oil exp on be deposited with the appropriate state bureau. This law has led to the velopment of "core libraries" which are now recognized as being extremely luable by companies which earlier had been most reluctant to contribute mples. Laws of this sort might be expanded to include not only cores taken the search for oil, but to include all cores, whether taken for engineering, ining, or petroleum exploration.

The interesting suggestion has also been made that in the case of those ites where engineers are licensed, duplicates of all reports made by mining d petroleum engineers in connection with exploration work and examinan of properties, should be filed with a state agency. Coincident with this ng, the client or the company for whom the report was prepared, would licate to the state agency the degree of "classification" they wished to ve imposed. Thus they could say, "no access to this report until further tification"; or "no access to this report until two years from date"; or lace on open file." By such a procedure a good deal of valuable material uld eventually be made available which otherwise would pass into dust some forgotten file.

Even without going to such rigorous lengths as passing laws, much can be ne toward building increasingly valuable central files by periodic canvass companies and individual operators who are willing from time to time release material no longer of interest to them but which still can provide iseful factual record on an area within the state concerning which no ormation might otherwise be available. Much can be accomplished, too, canvassing the schools in the state for work by students and staff related various areas, and for one reason or another not likely to reach the stage ormal publication.

We recommend the establishment, at both state and federal levels, of permanent minerals research advisory boards.

t both state and federal levels there is need for able, impartial, well-informed arch advisory boards which should be authorized and expected to do e than just give rubber-stamp approval to programs already operating, o screen proposals for federal- or state-fund sponsored research. They uld be in a position to recommend the *initiation* of programs that, in their nion, are particularly needed for the federal agency or the state concerned. he National Research Council, and its newer agency, the National Science ndation, have done a good deal along such lines, but more needs to be e. And as yet few if any of our states have any comparable advisory ds functioning in the field of the mineral industries. A permanent state erals research advisory board is indeed virtually required to guide the ctives, to establish priorities and to review budget matters for research

projects conducted by state bureaus and universities within their states w
state funds.

A permanent national advisory board comprising members from all parti
pating states might also be considered. This national mineral research
visory board could function as a coordinating agency to prevent duplicat
of effort and to see that all information from research projects is prope
disseminated.

6. *We recommend that mineral industry research laboratories be made*
integral part of the State Bureaus of Mines and Geology in each of
Western States.

For the eleven Western States, wherein are concentrated many of the m
eral riches of our Country, it is a matter of grave concern to find that in
all of them are first-class mineral research laboratories established, and resea
programs under way. The advanced technology of our manufacturing ind
tries as well as that of our mining and beneficiating industries require labo
tories especially designed for their respective purposes and a staff of scient
specialists. The greatest development of the natural resources of a state can
be realized without these. The scientific staff should be selected by the sa
high standards as the faculties of our colleges and universities. The limitati
of civil service must be realized just as much in this matter as in the case
our educational institutions. The highest ideal of integrity must be insis
upon, coupled with a passion for public service. The responsibility of p
gram planning and staff selection should be put on the director of the st
research agency and the state's research agency should be placed in cont
of a board of experts (the Minerals Research Advisory Board—Recommen
tion No. 5—could well fulfill this function) qualified by training and ex
rience in geology, physics, chemistry, engineering and economics.

This recommendation is not to be taken as duplicating in any way reco
mendation No. 1, concerning the establishment of research programs at u
versities and nonprofit foundations. A well-planned research program design
especially for the needs of the particular state can have an invigorating eff
on the entire state bureau which otherwise may develop into no more th
a bureau of archives. Important as proper keeping of the archives is, t
alone does not make for progress; but coupled with an active research p
gram it can make for a bureau best fitted not only to serve, but to furth
the mineral interests of the state.

In making this recommendation we wish, in particular, to urge all of t
Western States to push forward their programs of geologic mapping. T
kind of research has long been recognized as of fundamental importance
the mineral industry, yet even in our "best-mapped" states, there are s

e areas virtually unknown so far as basic geologic—or even topographic—
information is available. In programs of this type, the Federal Govern-
t has long shown a willingness to cooperate with the states. We urge that
several western states maintain initiative in *pushing to early completion*
topographic and geologic maps of the western United States wherein so
h of our mineral wealth is stored.

Ve recommend the establishment of a nonprofit foundation for accom-
lishing certain types of basic research for the mineral industries.

ne very critical matter is the alarming decline in the past 40 years of new
overies of new metal mining districts. This has been called to attention
early every leader who has had occasion to speak on the subject in recent
s. There is general recognition that we are now faced with an entirely
type of prospecting problem. The surface of the earth has been pretty
examined for outcrops of ore-bodies. Now we must learn to recognize
bodies which have not yet been exposed by erosion, or which have been
ed by surface detrital material after an earlier exposure to erosion. This
gnition can come from three currently available indirect procedures,
se methods must be refined to make them more useful: (1) geophysical,
geochemical and (3) geological, through better understanding of the
processes by which ore-bodies were formed.

here have been in the past few years several rather spectacular successes
buted to geophysical and geological methods: the Pima ore-body in
ona, the New Brunswick development in Canada, and the Indio Muerto
body in Chile are examples which suffice to prove the promise of the
hods. But as recently stated in a National Science Foundation subcom-
ee report, real "progress in the understanding of the genesis of ore de-
s has been negligible for many decades, and this is undoubtedly largely
onsible for the slow rate of improvement in geological techniques of dis-
ry. In no small part this is caused by a few geochemical roadblocks that
nt be removed by teams of chemists, geologists and physicists working
adequate research facilities."

he laboratory phases of such studies should proceed hand in hand with
studies; they are each integral parts of the same operation and maximum
gress on the theory of ore formation will not be achieved until a well-
grated field-laboratory approach is made. This requirement involves access
ne operating mining properties by the research teams. And it involves
ss in the *near future* before exploitation and final depletion of more dis-
s destroys much evidence vital to the study of ore-forming processes.
quote again from the National Science Foundation report: "Since many
ur mining districts are past their prime and mine workings are becoming

increasingly inaccessible and operating companies fewer, there is a ti e liness if not a positive urgency in the situation. If new geologic knowleg and principles are to be found and applied, it should be while still produc v districts remain accessible and in the hands of companies still financially al to apply them." California affords some prime examples to document ta statement.

Obviously, maximum cooperation from the operators must be accore the research group. But in order to get this, the companies must in t r be protected so that improper use is not made of their records a painfully acquired geological backgrounds. In order to insure the protect n of all concerned, the National Science Foundation subcommittee propo e that a separate nonprofit Foundation for Research in Mineral Deposits b established, responsible only to its own board of directors, and staffed a administered independently of any existing organization. It was further p posed that the foundation be financed by grants from the N. S. F. for least a five-year period. The total cost was estimated in some detail, to agg gate about $2,300,000 for five years.

VI. "APPENDIX"

WESTERN GOVERNORS MINERAL POLICIES CONFERENCE

October 7, 1955

. ARTHUR H. KENT, *Chairman*
ax Committee, Mills Tower
San Francisco, California

EAR MR. KENT: Inasmuch as some of the conclusions our committee has
ched have important implications for your Tax Committee, I am writing
personal letter to call your attention to some points which we of the
earch Committee sincerely hope you and your committee can consider
make recommendations upon.

irst of all, we are convinced that *the future of our domestic mining indus-*
lies in research. That this is not just a conclusion of a biased committee
that it applies not only to the mineral industry is borne out in a recent
cle by Ramond H. Ewell, a distinguished chemist *and* economist, who
, "Research may be the most important single factor in economic growth
ne United States."

y way of a hypthetical example let us take the case of the domestic
ome miner whose present plight has been so well brought out by our
eague, Joe Holman. For immediate relief in this industry and for the years
ediately ahead, a more realistic tariff policy and/or more generous domes-
ubsidies seem clearly to be the answers. But looking further ahead, one
nt foresee that increased research might discover that "Mineral X" (large
easily available quantities of which may occur in California) is a more
acceptable substitute for chromium. Thereby a new and more stable
stry is born, prices are lowered, and the consumer (that is, the general
ic) benefits. To be sure, the chromite miner would temporarily be
wn out of work; but with the creation of a *new* mineral industry, he
ally ends up having more and better opportunities for employment.

esearch indeed can cut two ways. By finding new minerals or new uses
established minerals it creates new demands for labor. By discovering
efficient methods of extraction, processing, utilization, etc., it leads to
r costs and increased sales. As is well said by Ewell, "Results of research
be likened to an economic double play."

cond, we recognize that *basic research is the material upon which applied*
rch and improved technology must feed. We also recognize that there
vitably a lag of anywhere from one to perhaps fifty years before certain
research can begin "to pay off." In a forward looking economy to

provide for soundly based industry in the future, then the "pure resear must be done today—and tomorrow, and all the time, and it must be c tinually expanded. Yet, as has been well said by one of our colleagues, as we emphasize in our report, "although most thoughtful people realize importance of basic research and realize the need for long-term progra yet legislators and budget-makers who are under constant pressure to taxes and to reduce expenditure, invariably find that projects on basic resea are the ones that are easiest to pare down or eliminate."

Third, we recognize that on the one hand applied research, particul in its most specific forms and if the need is great enough, will almost ine ably be accomplished by private industry and indeed this kind of resea should be done by private industry. *Basic research on the other hand sho properly be supported by public funds*, derived from the Federal Gove ment and from the several states, inasmuch as it is the general public t ultimately benefits.

Assuming these premises to be correct, then we of the Research Commit earnestly desire that you of the Tax Committee give some thought as to *best methods of assuring an adequate flow of funds to provide for b research in the mineral industry and for assuring not only adequacy continuity*. The necessity that research funds be not tied to political curre and to economic cycles is stressed in our report. Considering the time between the accomplishment of certain research studies and the "pay-o it is clear that research and the funds that support it should not be permit to fluctuate from year to year or from biennium to biennium.

Certainly our committee, without a single tax expert among us, would be so bold as to make any formal suggestions. A few comments howe may be in order, merely for what they may suggest to you and to y committee.

1. As a means of earmarking funds for research, we would in general opposed to state "severance taxes" or to any other kind of tax which pla an added burden on the mineral producer, for ultimately this is passed in the form of increased costs to the consumer and no one benefits. Furth more, such taxes operate to the specific detriment of the producers in th states which have severance taxes and who must meet competition w producers in states without the severance tax.

2. There may be something to be said for earmarking for research a p centage of customs duties collected on mineral imports, although such fu would probably be subject to wide fluctuations.

3. It has also been suggested that a percentage of income tax collected fr the mineral industry should be allocated to research. Such a suggestion m

l very well provided the funds are taken out of present tax and are not as an excuse to hike taxes on a particular industry.

A fixed amount (preferable perhaps to a fixed percentage) to be allo- l from general tax funds (federal and/or state) has much to be said for ut can law-makers and the voters who support them look far enough d to see the benefits that such a policy might ultimately bring to them? e know that we are handing a tough problem to you, but I sincerely that you and the members of your committee will be willing to take and wrestle it to a successful finish. If you can come up with a good er, and if eventually our governors and our Federal Government can ement your recommendations, you can feel that you have made a major ribution, not only to the benefit of our mineral industry but to the fit of the United States.

Cordially yours,

igned)

Ian Campbell, *Chairman*
Committee on Research

VII. ACKNOWLEDGMENTS AND REFERENCES

is committee has obtained much help and sound advice in the form of oral and written discussion, from its many friends in the minerals field. foregoing report inevitably represents a blend of our own ideas with of others. In some instances, not only the idea but even the phraseology be that of a friend from outside rather than inside the committee. Advice any friends was freely given, and it has been as freely used. If specific ations and citations have not been made, we trust that the fact that a in idea or a particular phrase has been embodied in the report will, under ircumstances, suffice for acknowledgment.

e committee has also consulted many references. A complete list would practical to provide here. Nevertheless the titles of a few publications h the committee has found to be of particular interest are perhaps worth ding here, for those who may wish further background in this important ct.

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INDEX TO VOLUME 52

A

ggregate, see Concrete aggregate
labaster Cave limestone deposit, El Dorado County, 451-452
lameda, borax refinery at, 280, 281
lberhill Coal & Clay Company clay pit, Riverside County, photo of, 65
lhambra gold mine, El Dorado County, 404-405; map of underground workings, 402, 403
lleghany area, geologic map of, in pocket; gold mines in, 237
lleghany-Downieville area, map showing mine locations in, in pocket
lluvial fan deposit, photo showing, 84
lluvial fans, as source of aggregate, 83
lpine gold mine, El Dorado County, 405-406; underground workings, 405
mador County, see Kennedy gold mine; Jones Butte clay mine
margosa Mining Company, 278
margosa Valley, borax in, 278, 280
merican Board of Promoters Boracic Acid Company, 282
merican Borax Company, 276, 282, 285, 286, 287
merican Potash & Chemical Corporation, 289
merican Trona Corporation, 288, 289
nnual Report of State Mineralogist, 9, 301
rgonaut Fraction gold mine, El Dorado County, 406
sbestos, El Dorado County, 441
ttapulgite, 118
uriferous gravels, 375
yers, W. O., 273
zurite, El Dorado County, 443

B

Bailey, Edgar H., *Report of the U. S. Geological Survey on cooperative studies of mineral deposits in California*, 72-77
Baker borax mine, San Bernardino County, 289
Baldwin gold mine, El Dorado County, 411-412
Ball clays, 122
Balling, W. M., 289
Barnes-Eureka gold mine, El Dorado County, 406
Bartlett, W. P., 282
Basin-Ranges province, clay in, 134-135
Bateman, Paul C., *Report of the U. S. Geological Survey on cooperative studies of mineral deposits in California*, 363-367
Beach sands, as source of aggregate, 88
Bear Creek tungsten mine, El Dorado County, 439
Beattie gold mine, El Dorado County, 436
Beebe gold mine, El Dorado County, 406-408; underground workings, 407
Beidellite, 118
Bentonite, 136, 141
Berg gold mine, El Dorado County, 411
Bernett soapstone property, El Dorado County, 455-456
Biddy McCarty borax mine, Inyo County, 286
Big Buzzard copper mine, El Dorado County, 394
Big Canyon gold mine, El Dorado County, 408
Big Sandy gold mine, El Dorado County, 408-409
Black Oak gold mine, El Dorado County, 409-411; underground workings, 410
Blue Canyon formation, 240
Blue Gouge gold mine, El Dorado County, 411
Blue Rock gold mine, El Dorado County, 436
Bonanza King chrome mine, El Dorado County, 391
Borax concentrates, photo showing sacking of, 284
Borax Consolidated, Ltd., 281, 282, 286, 289
Borax Lake, borax in, 273-275

Borax production, history of United States, 273-291
Borax Properties, Inc., 283
Borax refining, 279-281
Borosolvay, 288
Bowen, Oliver E., photo by, 66
Brandt, W. O., *Clay testing*, 145-149
Briarcliffe gold mine, El Dorado County, 411-412
Brighton Chemical Company, 285
Brogie, Ralph I., *Pyrometry*, 219-227
Brooklyn gold mine, El Dorado County, 406-408
Brush Creek gold mine, Sierra County, 247; map of, in pocket; photos showing 247, 249

C

Calaveras group, 374-375
Calico Mountains, borax in, 280
California Academy of Sciences, 280
California Borax Company, 273-275
California Rock and Gravel Company limestone quarry, El Dorado County, photo showing, 444
California Trona Company, 288
Californite, El Dorado County, 443
Calm & Brothers, M., borax refiners, 283
Cape Horn formation, 241
Carlson, Denton W., and Clark, William B., *Lode gold mines of the Alleghany-Downieville area, Sierra County, California*, 237-272; *Mines and mineral resources of El Dorado County, California*, 369-593
Casa Diablo hot springs, photo of, 61, 62
Cascade Lake, photo showing, 377
Castaic formation, 139
Chaix chrome mine, El Dorado County, 385
Chetco borate deposit, Oregon, 281, 282
Chico formation, 139
Chili Bar slate mine, El Dorado County, 453-455
Chrome Gulch chrome mine, El Dorado County, 392
Chromite, El Dorado County, 379, 384-393
Church gold mine, El Dorado County, 412-413
Clark, William B., and Carlson, Denton W., *Lode gold mines of the Alleghany-Downieville area, Sierra County, California*, 237-272; *Mines and mineral resources of El Dorado County, California*, 369-593
Clark, William B., photo by, 84
Clark gold mine, El Dorado County, 409-411
Clay, El Dorado County, 441; see also Alberhill Coal & Clay Company pit, Riverside County; Kraftile plant, Alameda County; Jones Butte mine, Amador County
Clay deposits, map showing California, in pocket
Clay Industries Conference of 1952, 111, 112
Clay industry, basic studies in, 111-227
Cleveland, George B., editor, *Basic studies in the clay industry*, 111-227
Cleveland, George B., photo by, 62
Coast Ranges province, clay in, 133
Cold Springs Sand & Gravel Company, 458-459
Coleman, William T., 280, 281
Coleman & Company, W. T., 278, 280
Colemanite, source of borax, 280-287
Colorado Desert province, clay in, 135
Colorado River, rock types along, 80
Columbian Mining & Chemical Co., 282
Columbus Borax Company, 282, 283, 285
Comeback Consolidated tungsten mine, El Dorado County, 439
Concrete aggregate, 79-104
Conglomerate, photo showing, 90
Conglomerates, as source of aggregate, 89
Conn & Trudo, borax producers, 282
Connell, D. D., 286
Cool-Cave Valley limestone deposit, El Dorado County, 443-445

opper, El Dorado County, 393-400
osumnes copper mine, El Dorado County, 394-395
osumnes gold mine, El Dorado County, 413
osumnes limestone deposit, El Dorado County, 452
oswell-Cave Valley limestone deposit, El Dorado County, 443-445
reigh, J. D., 276
rystal gold mine, El Dorado County, 413-414

D

arrington chrome mine, El Dorado County, 385
arrington copper mine, El Dorado County, 394
aunet, Isadore, 278
avey gold mine, El Dorado County, 409-411
avis, Fenelon F., photo by, 63, 69
ayton Consolidated gold mine, El Dorado County, 409-411
eath Valley, borax in, 278, 280, 281, 283-287
iamond Springs gold mine, El Dorado County, 419
iamond Springs Lime Company plant, El Dorado County, photo showing, 446; photo showing quarry, 447
iamond Springs Lime Corporation, El Dorado County, 445-446
iamonds, El Dorado County, 442
iasporite, 122
imension stone, El Dorado County, 441-442
ivision of Highways sand pit, El Dorado County, photo showing, 458
ivision of Mines exhibit, photo showing, 29, 30, 345
ivision of Mines laboratory, photo showing, 344
ivision of Mines library, photo showing, 32, 333
obbas chrome mine, El Dorado County, 385-386
odge & Company, T., 276
odson copper mine, El Dorado County, 398-399
olomite, El Dorado County, 442
onnelly chrome mine, El Dorado County, 292
ownie, William, 239
ownieville area, gold mines in, 237
owsing, William M., 288
redge tailings on Trinity River, photo showing, 86
redging, El Dorado County, 434-435
redging, sand and gravel from, 85
unes, as source of aggregate, 88

E

agle Borax Company, 278
ast Lode gold mine, El Dorado County, 406-408
l Dorado Crystal gold mine, El Dorado County, 413-414
l Dorado Chrome Company, 386-387; mill flowsheet, 386
l Dorado copper mine, El Dorado County, 395-396; photo showing, 395
Dorado County, geologic map of, in pocket; list of mineral deposits in, 463 ff.; map showing mines and mineral resources of eastern, in pocket; map showing mines and mineral resources of western, in pocket; mines and mineral resources, 369-593
Dorado Limestone Company, El Dorado County, 446-450; cross section of shrinkage stope, 449; photo showing plant, 448
pidote, El Dorado County, 443
speranza gold mine, El Dorado County, 425
ans, Elliott A. P., *Catalog of an old picture collection in the Division of Mines,* 40-44
ans, J. T., 280

F

ns, see Alluvial fans
ller clays, 148-149
re clays, 122
ring clays, 193-206
gstaff Hill area, geologic map and chromite mines, 388
nt clays, 122

Floodplain deposits, as source of aggregate, 83; photo showing, 83
Formhals borax refining process, 279, 282
Frazier Borate Mining Company, 283, 285
French Creek gold mine, El Dorado County, 414
Fullers earth, 136
Funny Bug gold mine, El Dorado County, 414
Furnace Creek, borax at, 278
Furnace Creek Ranch, steam tractor at, 278

G

Garnet, El Dorado County, 443
Garnierite, El Dorado County, 438
Gay, Thomas E., photo by, 83
Gem stones, El Dorado County, 442-443
Georgetown area, placer gold in, 431
Georgia Slide gold mine, El Dorado County, 436
Gerstley borax mine, Inyo County, 287
Gibbsite, 122
Glacial deposits, as source of aggregate, 87
Glacial till, see Till
Glaciation, photo showing Sierran, 378
Gold, El Dorado County, 400-437; Sierra County, 237-272; specimen, from El Dorad
  County, 443; see also, Kennedy mine, Amador County; Dredging
Gold Bluff gold mine, Sierra County, 250; underground map of, in pocket
Gold Coin gold mine, El Dorado County, 428
Gold Crown gold mine, Sierra County, 250-252; photo showing, 263
Gold mining, 1852, photo showing, 39
Gold Reserve gold mine, El Dorado County, 423
Goldman, Harold B., *Sand and gravel for concrete aggregate*, 79-104
Grand Victory gold mine, El Dorado County, 414-415
Grand View borax mine, Inyo County, 286
Granite, photo showing talus deposit of, 87
Great Valley province, clay in, 133
Greenland Salt & Borax Company, 278
Greenstone, 375; photo showing roadcut in, 374
Greenstone gold mine, El Dorado County, 406
Grit gold mine, El Dorado County, 415-416; mill flowsheet, 416
Grizzly Flat tungsten deposit, El Dorado County, 440
Gurney chrome mine, El Dorado County, 385

H

Hall, James L., *Temperature measurement in kilns*, 207-217
Hanna, G. D., 274
Hannum, J. L., 288
Harmony Borax Mining Company, 278
Harmony borax works, photo showing, 277
Harms gravel pit, El Dorado County, 459-460; photo showing, 459
Hart gold mine, El Dorado County, 436-437
Hartman, George, 286
Havilah gold mine, El Dorado County, 421-422
Hayden soapstone property, El Dorado County, 456
Hazel Creek gold mine, El Dorado County, 416-418; mill flowsheet, 417; underground workings, 418
Hercules copper mine, El Dorado County, 394
Hill, Mary, photos by 29, 30, 32, 61, 68, 87, 88, 89, 90, 94, 95, 98, 99, 333, 344, 345
Hillside group, gold, El Dorado County, 419
Huguenin, E., photos by, 284
Hursh, R. K., *The drying of clay products*, 177-191; *The firing process*, 193-206

I

Ibex talc mine, San Bernardino County, photo of, 63
Idlewild gold mine, El Dorado County, 427
Idocrase, El Dorado County, 443
Illite, crystal structure, 118; group of clays, 117-118, 139-140
Ilmenite, El Dorado County, 439

iperial County, see Pioneer manganese mine
ne formation, 133, 134, 138, 139
wa gold mine, El Dorado County, 406-408
elan (Ireland) gold mine, Sierra County, 254-255; map of underground workings, in pocket
on ore deposits, El Dorado County, 437

J

mes Marshall gold mine, El Dorado County, 408-409
nkins, Olaf P., *Annual report of the State Mineralogist . . . for the 106th fiscal year*, 9-77; . . . *for the 107th fiscal year*, 301-367; photo by, 86
erger chrome mine, El Dorado County, 387
nes Butte clay mine, Amador County, 143

K

naka formation, 240; photo showing, 241
olinite, crystal structure, 116; group of clays, 115-116, 136-139
te Hardy gold mine, Sierra County, 253-254; cross section of underground workings, in pocket
lsey gold mine, El Dorado County, 418-419
nnedy gold mine, Amador County, photo of, 89
rnite, 288, 289
lns, temperature measurement in, 207-217
iapp, W. J., *Properties of clays*, 125-130
ioxville shale, 139
ehn Lake, borax in, 276
aftile plant, photo showing, 68
amer district, 287-289
eyenhagen formation, 141

L

dy gold mine, El Dorado County, 418-419
ke County, borax in, 273-275
ke Hachinhama, borax in, 274-275
rkin gold mine, El Dorado County, 419, 442
st Chance gold mine, El Dorado County, 411-412
ad deposits, El Dorado County, 437
ad-zinc, Darwin area, 75-76
dicoat gold mine, El Dorado County, 415-416
a C. colemanite mine, Inyo County, 283, 285, 286, 287
nestone, El Dorado County, 443-452; deposit, photo showing, 66
tle Borax Lake, borax in, 274
tle Emma copper mine, El Dorado County, 397-398
tle Placer borax mine, San Bernardino County, 289
man, L. H., *Testing of clays*, 151-154
Angeles Branch office, 69-71, 358-360; photo showing, 70, 72
Angeles rattler, photo showing, 95
ell, F. M., 286
ver Biddy borax mine, Inyo County, 286

M

achite, El Dorado County, 443
nganese, see Pioneer mine, Imperial County
nganese deposits, El Dorado County, 437
ble Valley limestone deposit, El Dorado County, 450-451
riposa formation, 375
rtinez gold mine, El Dorado County, 419
Laren, discoverer of colemanite at Frazier Mountain, Ventura County, 283
rten formation, 375-376
ton gold mine, El Dorado County, 413
idian Borax Company, 278
roscope, photo showing, 94
dle End gold mine, El Dorado County, 413
e dumps, as source of aggregate, 88
eral paint, El Dorado County, 452
elo formation, 139

Mojave Desert, clay in, 134-135
Mokelumne River, placer gold in, 431-433
Molybdenum, El Dorado County, 437
Monarch-Sugar Loaf gold mine, El Dorado County, 419-420
Montauk Consolidated gold mine, El Dorado County, 429
Montezuma-Apex gold mine, El Dorado County, 420-421
Montezuma Extension gold mine, El Dorado County, 420-421
Montmorillonite, crystal structure, 117
Montmorillonoid group of clays, 116-117, 141-142
Mother Lode, El Dorado County, 401, 404
Mott and Piper, borax producers, 276
Mount Diablo coal field, first California clay mined from, 134
Mount Pleasant gold mine, El Dorado County, 421
Mount Tallac, photo showing, 377
Mudd, Harvey S., 289; Henry T., 289; Seeley G., 289
Mugwump gold mine, Sierra County, 255
Mulvey Point gold mine, El Dorado County, 436
Murphy chrome mine, El Dorado County, 387

N

Nashville gold mine, El Dorado County, 421-422
National Borax Company, 286
National gold mine, El Dorado County, 411-412
National minerals policy, recommendations for a, 595-656
Neel borate mine, 286
Neuschwander, R., 280
Nevada, borax in, 275, 276, 278, 279, 280, 282, 286
Nevada City, photo showing placer mining near, in 1852, 39
Nevada Salt and Borax Company, 276, 278, 282
Nickel deposits, El Dorado County, 438
Nillson chrome mine, El Dorado County, 392
Noonday copper mine, El Dorado County, 396-397
Novato conglomerate, 89

O

Oakley borax mine, Inyo County, 286
Oil-well drilling mud, 136
Opal, El Dorado County, 443
Optical pyrometer, diagram of, 221
Oriental gold mine, Sierra County, 255-259; map of underground workings, i
pocket
Oro Fino gold mine, El Dorado County, 408
Osceola gold mine, Sierra County, 259-262
Owens, Judge A. J., 282
Owens Lake, borax production from, 289
Oxford gold mine, Sierra County, 258, 259

P

Pacific Borax & Redwoods Chemical Works, Ltd., 281
Pacific Borax Company, 276, 277, 278, 279, 280, 281, 282
Pacific Coast Borax Company, 283, 285, 286, 287, 288, 289; photo of rotar
roasters, 284
Pacific gold mine, El Dorado County, 436
Pacific Minerals Company slate mine and plant, El Dorado County, photo show
ing, 454
Pacific Minerals soapstone mine, El Dorado County, 456-457
Palm Borate Company, 282
Parsons gold mine, El Dorado County, 436
Partz, Dr., 275
Pask, Joseph A., 112; *Clays and clay mineralogy,* 113-123; *Soluble salt deposit*
on clay wares, 155-165
Pendelco gold mine, El Dorado County, 414
Peninsular Ranges province, clay in, 134
Periodic kilns, 214-217
Perkins, John, 286

llikin (Pilliken) chrome mine, El Dorado County, 387-393; photo showing, 389
llikin Mining Company, flowsheet of chrome mill, 390
oneer-Lilyama copper mine, El Dorado County, 397-398
oneer manganese mine, Imperial County, photo of, 63
ttsburgh Plate Glass Company, 289
acerville area, map showing placer mines and Tertiary gravels, 432; placer gold
n, 433-434
acerville Gold Mining Company, El Dorado County, 422-423
asticity of clays, 125
atinum-group metals, El Dorado County, 438
aya borax deposits, 275-280, 282
ayed Out borax mine, Inyo County, 286
iceite, 281
ramid gold mine, El Dorado County, 423
rometric cones, 207-209
rometry, 219-227

Q

artz crystals, El Dorado County, 443
icksilver deposits, El Dorado County, 438

R

diamatic thermopile, diagram of, 226
diation pyrometer, diagram of, 220
dioactive minerals, El Dorado County, 438
sor, Clarence M., 287, 288
sorite, 288
ttlesnake Bar limestone deposit, El Dorado County, 451-452
ttlesnake Bridge limestone deposit, El Dorado County, 451-452
d Star gold mine, Sierra County, 259-262
dding Branch Office, 71-72, 361-362
fractoriness of clays, 120
fractory clays, 147-148
lief formation, 241
sidual clays, 136-137
odes and Wasson, borax processors, 276
p and Tear copper mine, El Dorado County, 398-399
verside County, see Alberhill Coal and Clay Company clay pit
-Tap sieve shaker, photo showing, 98
gers, Burt, photo by, 65
osevelt copper mine, El Dorado County, 395-396
scoelite, 426
se Valley Borax Company, 282
secranz (Rosecrans) gold mine, El Dorado County, 423-424
ssell Borate Company, 285
an borax group, Inyo County, 286, 287

S

ramento Branch Office, 71, 360-361
ine Valley Borax Company, 278
t, photo showing stockpile, 66
t Wells Valley, borax in, 276, 282
n Bernardino Borax Mining Company, 276, 278, 279, 280, 282, 288
n Bernardino County, see Ibex talc mine
n Pedro formation, 88
nd and gravel, 79-104
nd-equivalent test, photo showing, 99
nta Margarita formation, 89
aller, W. T., 288
walin limestone deposit, El Dorado County, 450-451
m deposits of gold, El Dorado County, 435-437
rles, Dennis, 277; John W., 276
rles Lake, borax from, 276-280; 282, 286, 288, 289
beck's principle of flow of current in thermocouple, diagram of, 222
er, inventor of pyrometric cone, 207
ion Lime Company plant, El Dorado County, photo showing, 450

Serpentine, El Dorado County, 376; Sierra County, 241
Shan Tsz gold mine, El Dorado County, 424-425
Shaw gold mine, El Dorado County, 424-425
Shillings, E. W., 276
Shrinkage of clay wares, 201
Sierra County, gold mines in Alleghany-Downieville area, 237
Sierra foothills mineral belt, exploration in, 73-74
Sierra Nevada province, clay in, 133
Sierra Placerite, El Dorado County, 441-442
Sieves, for separating aggregates, photo showing, 98
Silica, El Dorado County, 452-453
Silver, El Dorado County, 439
Sixteen-to-One gold mine, Sierra County, 262-267
Sixteen-to-One vein, photo showing, 241
Skipper gold mine, El Dorado County, 425
Slate, El Dorado County, 453-455
Sliger gold mine, El Dorado County, 425-426
Slug Gulch limestone deposit, El Dorado County, 452
Smith, F. M., 275, 286, 289
Smith Brothers, borax producers, 278, 279, 280
Soapstone, El Dorado County, 455-457
Soda ash, 288
Solvay Process Company, 288
Spanish Dry Diggings gold mine, El Dorado County, 415-416
Spears, John R., 280, 281
Springfield gold mine, El Dorado County, 427-428
Standard Sanitary Company, 282, 286
State Mineralogist, annual report of, 9, 301
Stauffer Chemical Company, 282, 283, 285
Steam engines, in borax mining, 283; photo of, 277
Sterling Borax Company, 285
Stevens, B. F., 283
Stiff-mud forming, 172-175
Stone, El Dorado County, 457-460
Stream channels, as source of aggregate, 81
Stream terraces, as source of aggregate, 82
Stuckslager gold mine, El Dorado County, 426
Suckow, Dr. J. K., 287
Suckow Chemical Company, 287, 289
Sugar Loaf gold mine, El Dorado County, 426
Sutherland, Clark, *Clay preparation and stiff-mud forming methods*, 167-175
Swift soapstone mine, El Dorado County, 456-457

T

Talc, see Ibex mine, San Bernardino County
Talus deposit, photo showing, 87; as source of aggregate, 87
Taylor gold mine, El Dorado County, 427
Teels Marsh Borax Company, 276, 278
Tehama County, discovery of borax in, 273
Temperature measurement in kilns, 207-217
Tennessee-Nashville gold mine, El Dorado County, 421-422
Tertiary channels, El Dorado County, map of, 430
Thermocouple pyrometer, 221-227
Thermoelectric pyrometer, diagram of, 222
Thorkildsen & Company, Thomas, 283, 285
Tick Canyon, colemanite in, 285
Tightner formation, 240; photo showing, 239
Till, photo showing deposit of, 88
Titanium, El Dorado County, 439
Transported clays, 137-140
Transverse Ranges province, clay in, 134
Trinity River, photo showing, 86
Troup, William, 275
Tungsten, El Dorado County, 439-440
Tunnell kilns, 210-214

urner, Mort D., photo by, 66; and Wisser, E. H., *Mineral exploration and winning of clays*, 131-144
uscan Springs, discovery of borax in, 273
wenty-mule teams, 279-280, 281

U

lexite, source of borax, 275, 278, 279, 287
nion Borax Company, 286
nion gold mine, El Dorado County, 427-428
nited States Borax Company, 287, 288
nited States Geological Survey, report of, 72-77, 363-367
ranium, El Dorado County, 438
niversity of California, Clay Industries Conference at, 111, 112

V

alley Springs formation, 375
andalia gold mine, El Dorado County, 428
apor-filled thermal system, diagram of, 219
eatch, J. A., discoverer of borax, 273, 275
eerkamp gold mine, El Dorado County, 428
er Planck, W. E., *History of borax production in the United States*, 273-291
icat Needle clay test, 152
itrification of clay wares, 201
olo copper mine, El Dorado County, 397-398
olo gold mine, El Dorado County, 424-425
olo mill, El Dorado County, 399-400; flowsheet of, 399; photo showing, 397
onsen, M., 274

W

alker chrome mine, El Dorado County, 393
ashington, borax in, 286, 287
atersmoking, 193
est Baker borax mine, San Bernardino County, 289
est End Chemical Company, 286, 287, 288, 289
estern Borax Company, 289
estern borax mine, San Bernardino County, 289
estern Governors Minerals Policies Conference, 595-656
estern Minerals Company, 282
hiteware clays, 145-147
idow borax mine, Inyo County, 286
illiams tungsten prospect, El Dorado County, 440
ilmington, borax refinery at, 281, 288
inters, Aaron, 278
isser, E. H., and Turner, Mort D., *Mineral exploration and winning of Clays*, 131-144
onder gold mine, Sierra County, 250
oodside-Eureka gold mine, El Dorado County, 406-408
right, Lauren A., photos by, 63, 70, 72

Y

ellow Jacket gold mine, Sierra County, 269-272
oung America gold mine, Sierra County, 255

Z

antgraf (Zentgraf) gold mine, El Dorado County, 429
nc, El Dorado County, 440-441

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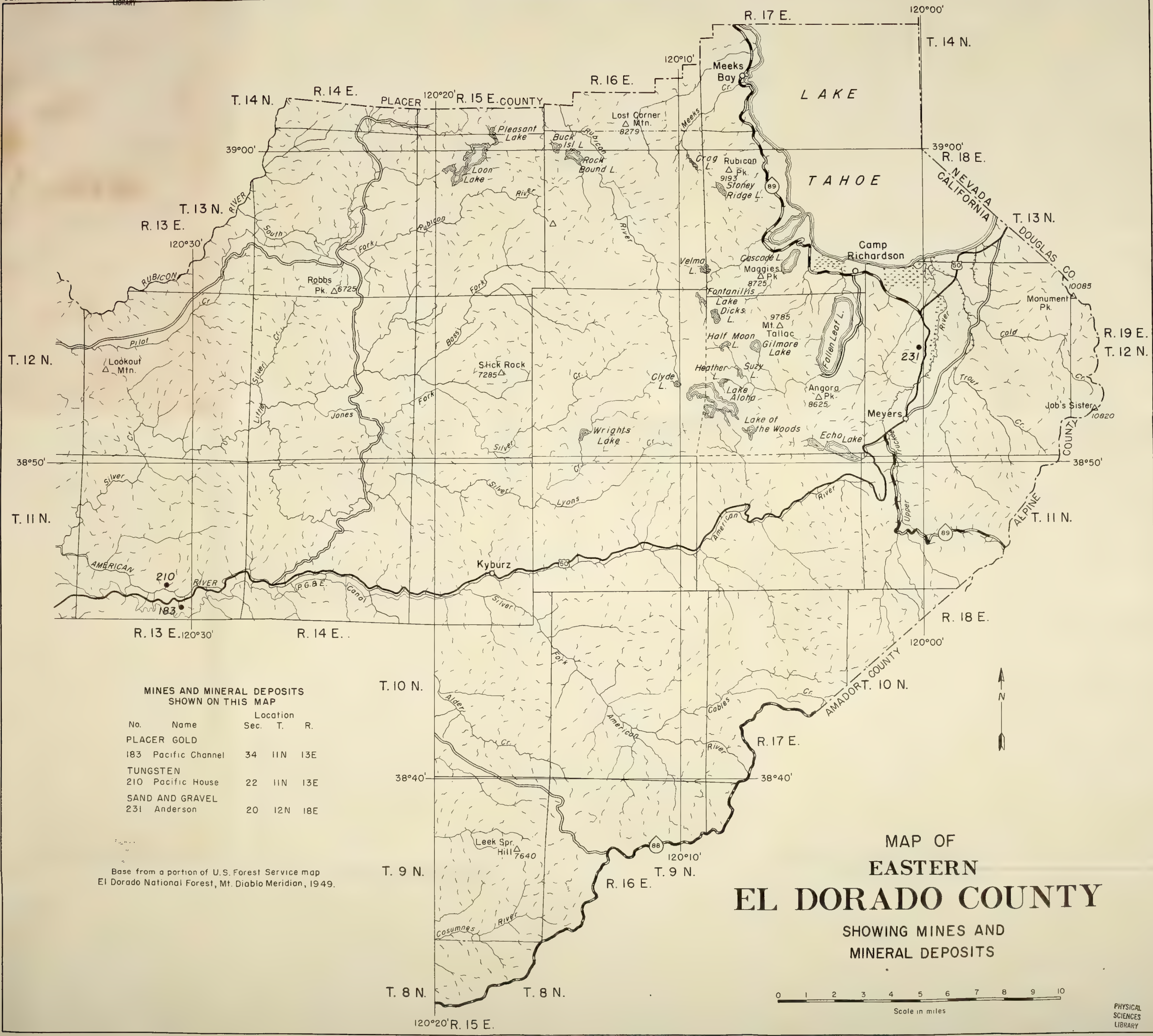
R. 17 E.
120°00'
T. 14 N.
120°10'
Meeks Bay
LAKE
TAHOE
R. 16 E.
T. 14 N.
R. 14 E.
PLACER
120°20'
R. 15 E.
COUNTY
Lost Corner Mtn. 8279
Pleasant Lake
Buck Isl L.
Rubicon
Meeks Cr.
39°00'
Loon Lake
Rock Bound L.
Crag L.
Rubicon Pk. 9193
Stoney Ridge L.
89
39°00'
R. 18 E.
NEVADA
CALIFORNIA
T. 13 N.
R. 13 E.
River
South
Rubicon
Fork
River
120°30'
RUBICON
Robbs Pk. 5725
Fork
Velma L.
Cascade L.
Maggies Pk 8725
Camp Richardson
50
DOUGLAS CO.
10085
Monument Pk.
Pilot Cr.
Silver Cr.
Bassi Fork
Fontanillis Lake
Dicks L.
9785 Mt. Tallac
Fallen Leaf L.
T. 12 N.
Lookout Mtn.
Half Moon L.
Gilmore Lake
231
River
Cold
R. 19 E.
T. 12 N.
Little
Slick Rock 7285
Cr.
Heather L.
Suzy L.
Clyde L.
Lake Aloha
Angora Pk. 8625
Trout
Cr.
Jones
Fork
Meyers
Job's Sister 10820
Cr.
Silver
Wrights Lake
Lake of the Woods
Echo Lake
Cr.
Cr.
COUNTY
38°50'
38°50'
Silver
Silver
Lyons
Cr.
American
River
Truckee
Upper
T. 11 N.
ALPINE
T. 11 N.
89
AMERICAN
210
RIVER
Kyburz
50
P.G.&E. Canal
183
Silver
R. 13 E.
120°30'
R. 14 E.
R. 18 E.
120°00'
Fork
AMADOR COUNTY
T. 10 N.
T. 10 N.
N
Alder Cr.
Cables Cr.
American
River
R. 17 E.
38°40'
38°40'
Leek Spr. Hill 7640
88
120°10'
T. 9 N.
T. 9 N.
R. 16 E.
Cosumnes River
T. 8 N.
T. 8 N.
120°20'
R. 15 E.
0 1 2 3 4 5 6 7 8 9 10
Scale in miles

MINES AND MINERAL DEPOSITS
SHOWN ON THIS MAP

No.	Name	Location Sec.	Location T.	Location R.
PLACER GOLD				
183	Pacific Channel	34	11N	13E
TUNGSTEN				
210	Pacific House	22	11N	13E
SAND AND GRAVEL				
231	Anderson	20	12N	18E

Base from a portion of U.S. Forest Service map
El Dorado National Forest, Mt. Diablo Meridian, 1949.

MAP OF
EASTERN
EL DORADO COUNTY
SHOWING MINES AND MINERAL DEPOSITS

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